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CIVIL ENGINEERING.

Essay on the Stadia. By JOHN R. MAYER, C. E.

To the Editor of the Journal of the Franklin Institute.

MR. EDITOR:—I address you an Essay on the *Stadia* with explanations of the principles for computing *graphically* the difference of level and the reduction to the horizon, from observed altitudes and distances obtained with the Stadia. At the same time I beg to make a short retrospection on the subject of *Topography* in order to show the cause of the slow introduction of the *Stadia* in the Topographical Surveys of various countries in Europe.

Topography was not known before the *end of the last century*, for it could not be proper to give that name to a kind of *perspective* lying over the horizontal plane, for the representation of *fancy* crests, or tops of hills, as we see it on the old maps or charts.

The Topographical representation of the ground by means of horizontal curves, was invented by *Ducarla** of Geneva, Switzerland, at the epoch above mentioned, and has since been adopted with success by all the corps of Engineers.

Ducarla's mode was the first step to obtain a true representation of the ground, but required an instrument for the determination of the exact position of the horizontal curves, the use of an ordinary

*See, Puissant, Traité de Topographie, page 226, Paris, 1820.

leveling instrument with a chain being too slow an operation for making a Topographical Survey of some extent.

The idea to measure the distances by a scale and the micrometer of a telescope was proposed by an Italian engineer about 45 years ago, and the name of Stadia (Scale) was given by him to that kind of measure.

The *Stadia* gives but a distance on the inclined plane of Sight, and requires the observation of an altitude for obtaining the difference of level and the reduction to the horizon, which operations are to be done by computation.

To facilitate the work, some engineers made *Tables* for computing the altitudes and the reduction to the horizon, which give a result by interpolation but is a slow and tedious operation.

Such was the progress of the introduction of the *Stadia* for a Topographical and Military Survey, that when, in 1836, the Government of the Swiss Confederacy ordered the Survey of Switzerland, and placed it under the Superintendence of General G. H. Dufour of Geneva.

Before 1836 the Governments of France, Germany, and Italy, had begun the Topographical Survey of their countries, but did not make any improvements in the instruments used for Topography, on account of the facilities they had to make use of all the land Surveys already made. The work of their charts being but to co-ordinate the reductions of the land Survey to a triangulation and to draw the relief of the ground according to some principal elevations obtained from the altitude of trigonometrical points and by a direct leveling, without measuring any distance, the rest of the work being done by sketching. In England the *Ordnance Survey* comprising the land Survey, the Topography was executed in a manner similar to the above mentioned countries.

At the date of 1836, Switzerland had no land Survey, which could be used for the Topographical and Military Survey ordered by the government; it was then necessary to make use of the *Stadia* for the determination of the detail which was to be co-ordinated to a triangulation; consequently it was necessary to unite exactness with rapidity of operation.

Experience of more than 25 years have proved that the Stadia can be used instead of a chain for making a Topographical Survey, which rests on a triangulation.

From the beginning of the Topographical Survey of Switzerland, it appeared obvious that the use of the *Tables* mentioned above, was too slow an operation for the computation of altitudes and reduction to the horizon of points obtained with the Stadia. This want of prompt results led two officers engaged in this Topographical Survey to find a way of making *graphically* these computations. Here I must say that the *principle* and *construction* of the quadrant for the computation of altitudes belong to my old colleague C. Volfschberger of Geneva, and the *principle* and *construction* of the diagram for the reduction to the horizon of any distance measured by *the Stadia* or *the chain*, is my own.

These two modes of computing *graphically* have been used *only* by

the assistants of the Federal Survey of Switzerland and have never been yet published.

The *Stadia* has been used in the Topographical Surveys which Col. Richard Delafield, Chief of the U. S. Corps of Engineers, and late Lieut. M. Harrison, U. S. Engineers, entrusted me with in 1850 and 1851; and the use of this instrument and these two modes of graphical computations have been approved by Col. J. D. Graham, U. S. Corps of Engineers for Topographical Surveys made by me under his direction since 1855; and also by Col. W. F. Reynolds, A. D. C. Major Corps of Engineers, U. S. Army, Superintendent of U. S. Lake Survey in the instructions given this year (1864) for the operations of the U. S. Lake Survey.

I now come to explain the use of the Stadia, and also how these quadrants and diagrams are made.

I. *Construction of a Stadia.*

This instrument is constructed on the principle that the distance that separate objects of different dimensions from the observer seeing them under the same visual angle, are proportional to their respective dimensions.

The manner adopted for constructing a *Stadia* is explained as follows, viz:

Let A O B (Fig. 1, Pl. I,) be a visual angle having its vertex O at the eye of the observer, and the sides A O and B O formed by the visual rays which proceed from O and pass through two wires fixed on the diaphragm of a telescope; these sides being produced to the staff C D placed at a known distance O E, will intersect the staff in the two points F and G, which mark a space F G which represent the distance O E.

Consequently if an horizontal line C H equal to O E is measured and the staff C D set up vertically at C in dividing the space F G into as many parts as the distance C H contains units, the scale of the *Stadia* will be known.

The triangle F O G is divided in two right angled triangles F O E and E O G which have both the two sides adjacent to the right angle known; then the angles F and G can be computed.

As the spaces E F and E G depend on the distance of the horizontal wires to the central wire on the plane of the axis of the telescope; if these spaces are not equal then there will be a different value for each angle F and G.

The distance between two points is measured with the Stadia on the inclined plane of sight, therefore the normal position of the Stadia to the axis of the telescope, is an important condition for the true reading of the distance, but knowing the difficulty of holding the staff in such a position, it is better to keep it always vertical, and compute the error of the reading on the Stadia scale.

The length and division of a Stadia are made according to the power of a telescope, and the space between the wires fixed on its diaphragam. Consequently it is necessary to observe that the space A B (Fig. 1, Pl. I,)

when produced on the staff C D must not exceed *nine feet* from F to G for the greatest distance given with the telescope, say 2000 feet.

The scale of a Stadia is painted black on a white staff and is divided as shown in Fig. 2. But the space between two divisions of 5 feet is estimated according to the position of the wires.

II. *Correction of the Verticality of the Stadia.*

Let O (Fig. 3, Pl. I,) be the station of the observer, F G the space which represents on the Stadia, C D a distance under the visual angle F O I, which requires a correction so as to be reduced to I K which gives the true distance from O to E, when the Stadia is in a normal position to the central ray O E passing through the axis of the telescope and L O E = K E F = G E I = δ the observed altitude.

The triangles E G I and E K F not being similar, give the following results.

For the triangle E G I we have, E G : E I :: sin I : sin G; but G = 180°–E–I, hence sin G = sin (E+I).

Consequently $EI = EG\left(\frac{\sin(E+I)}{\sin I}\right) = EG\,\frac{(\sin E\cos I+\sin I\cos E)}{\sin I}$

$= EG(\sin E\cot I+\cos E)$ . . . (1)

The triangle E K F gives also:

$EK = EF(\sin E\cot K+\cos E)$ . . (2)

Adding (1) and (2) we have

$IK = FG(\sin E(\cot I+\cot K)+\cos E)$. (3)

The angle E or δ being small, its sine is also small. The angles I K are both very near of 90°, consequently their cotangent is small, and compared to the value of cos E or cos δ, the product of these two trigonometrical lines can be omitted.

Then by eliminating these small values and representing F G by l we have

$$IK = l\cos\delta \quad . \quad . \quad (4)$$

which is the formula for the true reading on the Stadia corrected for the verticality of any distance on the inclined plane of sight.

The repetition of a distance on the Stadia may be obtained easily by taking many readings at different altitudes and noting each time the value of δ, δ', δ'', δ''', &c., the mean of these observations applied to (4) will be the exact distance O E corrected of the verticality of the Stadia.

III. *The difference of level between two points,*

is obtained by simply multiplying the sine of the observed altitude by the distance corrected for the verticality of the Stadia, which is to multiply the value of I K by sin δ, consequently h being the difference of level, l the distance given by the Stadia, and δ the observed altitude, we have

$$h = l\sin\delta\cos\delta \quad . \quad . \quad (5)$$

IV. *The reduction to the horizon of any distance given by the Stadia with correction for its verticality*, may be computed with both formulæ.

$$r = l \cos^2 \delta \ (6); \quad l - r = l \sin^2 \delta \quad . \quad . \quad (7)$$

l being a distance given by the Stadia; δ an observed altitude; and r the same distance reduced to the horizon.

V. *Quadrant for computing the difference of level between two points, with correction for the verticality of the Stadia.*

The formula used is (5).

Principle.

Let Fig. 4, (Pl. I,) an altitude be given and its sine multiplied by its cosine produces a certain angle called x; let the sine of x be A B; if the line A B is produced as to make A C = 10 times A B by drawing C D parallel to A O until it intersects the arc A D at D, the line D E will represent the sine of an angle y and will be ten times greater than the sine A B. Now if rather than take on O B the distances to be multiplied by the sine of x, they are taken on the line O D, they will be multiplied by the sine of y and consequently the product will be ten times greater:

Construction of a quadrant: with the table of logarithms it is easy to compute the angles from *two* to *two* minutes and to trace on the quadrant every result (by using a protractor, or the table of chords) until the sine $x \times 10 =$ *the radius*. This will be the limit of the first quadrant, or quadrant A.

$$\text{Then, } h = y \times 0{\cdot}1 \quad . \quad . \quad (8)$$

The quadrant B is obtained by subtracting the *radius* from the value in number of the logarithm of the sine $x \times 10$ and finding the value of the logarithm of the remainder in degrees.

$$\text{Then, } h = (y + l)\ 0{\cdot}1 \quad . \quad . \quad (9)$$

The quadrant C is obtained by subtracting twice the *radius* and doing for the rest the same operation as for the quadrant B.

$$\text{Then, } h = (y + 2\,l)\ 0{\cdot}1 \quad . \quad . \quad (10)$$

The quadrant D is also obtained by subtracting three times the *radius* and making the rest of the computation as for the quadrant B or C.

$$\text{Then, } h = (y + 3\,l)\ 0{\cdot}1 \quad . \quad . \quad (11)$$

The results of these computations are shown in the following tables:

TABLE I, *for the construction of the Quadrant* A. Fig. 5, Plate I.

Observed altitude.	Value of $x \times 10$ in degs.	Observed altitude.	Value of $x \times 10$ in degs.	Observed altitude.	Value of $x \times 10$ in degs.	Observed altitude.	Value of $x \times 10$ in degs.
0° 02′	0° 20′	1° 32	15°31′	3° 02	31° 54′	4° 32′	51° 59′
04	40	34	15 51 40	04	32 17	34	52 32
06	1 00	36	16 12 30	06	32 41	36	53 04
08	1 20	38	16 33 10	08	33 05	38	53 37
10	1 40	40	16 54	10	33 29	40	54 11
12	2 00	42	17 15	12	33 52	42	54 45
14	2 20	44	17 36	14	34 16	44	55 19
16	2 40	46	17 57	16	34 40	46	55 54
18	3 00	48	18 18	18	35 05	48	56 30
20	3 20	50	18 39	20	35 29	50	57 06
22	3 40	52	19 00	22	35 54	52	57 42
24	4 00	54	19 21	24	36 18	54	58 19
26	4 20	56	19 42	26	36 43	56	58 57
28	4 40	58	20 03	28	37 08	58	59 36
30	5 00	2 00	20 25	30	37 33	5 00	60 15
32	5 20	02	20 46	32	37 57	02	60 55
34	5 40	04	21 07	34	38 23	04	61 36
36	6 01	06	21 29	36	38 48	06	62 18
38	6 21	08	21 50	38	39 14	08	63 01
40	6 41	10	22 12	40	39 39	10	63 45
42	7 01	12	22 33	42	40 05	12	64 30
44	7 21	14	22 55	44	40 31	14	65 16
46	7 41	16	23 17	46	40 57	16	66 04
48	8 02	18	23 38	48	41 24	18	66 53
50	8 22	20	24 00	50	41 50	20	67 44
52	8 42	22	24 22	52	42 17	22	68 37
54	9 02	24	24 44	54	42 44	24	69 33
56	9 22	26	25 06	56	43 11	26	70 29
58	9 43	28	25 28	58	43 38	28	71 30
1 00	10 03	30	25 50	4 00	44 06	30	72 34
02	10 23	32	26 12	02	44 33	32	73 41
04	10 43 36	34	26 35	04	45 01	34	74 54
06	11 04	36	26 57	06	45 29	36	76 12
08	11 24 20	38	27 19	08	45 58	38	77 39
10	11 44 44	40	27 42	10	46 26	40	79 17
12	12 05	42	28 04	12	46 55	42	81 13
14	12 25 30	44	28 27	14	47 24	43	82 22
16	12 46	46	28 50	16	47 54	44	83 43
18	13 06 34	48	29 12	18	48 24	45	85 27
20	13 27	50	29 35	20	48 53	46	88 37
22	13 47 40	52	29 58	22	49 24		
24	14 08 15	54	30 21	24	49 54		
26	14 29	56	30 44	26	50 25		
28	14 49 30	58	31 07	28	50 56		
30	15 10 10	3 00	31 30	30	51 28		

Limit of the Quadrant A = 5° — 46′ — 06″.

TABLE II, *for the Construction of the Quadrant* B. Fig. 6, Plate I.

Observed altitude.	Value of $x \times 10 - B$, in degs.	Observ'd altitude.	Value of $x \times 10 - B$, in degs.	Observ'd altitude.	Value of $x \times 10 - B$, in degs.	Observ'd altitude.	Value of $x \times 10 - B$, in degs.
5° 48′	0° 18′	7° 20′	15° 25′	8° 52′	31° 32′	10° 24′	50° 51′
50	0 38	22	15 45	54	31 54	26	51 21
52	0 58	24	16 06	56	32 16	28	51 51
54	1 17	26	16 26	58	32 39	30	52 21
56	1 37	28	16 46	9 00	33 02	32	52 51
58	1 56	30	17 06	02	33 25	34	53 22
6 00	2 16	32	17 26	04	33 47	36	53 54
02	2 36	34	17 46	06	34 10	38	54 26
04	2 55	36	18 07	08	34 33	40	54 59
06	3 15	38	18 27	10	34 56	42	55 31
08	3 35	40	18 48	12	35 20	44	56 04
10	3 54	42	19 08	14	35 43	46	56 38
12	4 14	44	19 28	16	36 06	48	57 12
14	4 33	46	19 49	18	36 30	50	57 47
16	4 53	48	20 09	20	36 54	52	58 22
18	5 12	50	20 30	22	37 18	54	58 57
20	5 32	52	20 50	24	37 41	56	59 34
22	5 51	54	21 11	26	38 05	58	60 11
24	6 11	56	21 31	28	38 29	11 00	60 49
26	6 31	58	21 52	30	38 53	02	61 27
28	6 50	8 00	22 13	32	39 18	04	62 06
30	7 10	02	22 34	34	39 42	06	62 46
32	7 30	04	22 55	36	40 07	08	63 27
34	7 49	06	23 16	38	40 32	10	64 09
36	8 09	08	23 37	40	40 57	12	64 52
38	8 29	10	23 58	42	41 22	14	65 36
40	8 49	12	24 19	44	41 47	16	66 21
42	9 08	14	24 40	46	42 12	18	67 08
44	9 28	16	25 01	48	42 38	20	67 57
46	9 47	18	25 22	50	43 03	22	68 47
48	10 07	20	25 43	52	43 29	24	69 39
50	10 27	22	26 05	54	43 55	26	70 33
52	10 46	24	26 26	56	44 21	28	71 29
54	11 06	26	26 47	58	44 48	30	72 29
56	11 26	28	27 09	10 00	45 14	32	73 32
58	11 46	30	27 30	02	45 41	34	73 39
7 00	12 06	32	27 52	04	46 08	36	75 51
02	12 26	34	28 14	06	46 36	38	77 10
04	12 46	36	28 35	08	47 03	40	78 38
06	13 06	38	28 57	10	47 30	42	80 18
08	13 25	40	29 19	12	47 58	43	81 16
10	13 45	42	29 41	14	48 27	44	82 20
12	14 05	44	30 03	16	48 55	45	83 35
14	14 25	46	30 25	18	49 23	46	85 08
16	14 46	48	30 46	20	49 52	47	87 32
18	15 05	50	31 09	22	50 22		

Limit of the Quadrant B=11°—47′—21″.

TABLE III, *for the Construction of the Quadrant* C. Fig. 7, Plate I.

Observ'd altitude.	Value of $x \times 10-2R$, in degs.	Observ'd altitude.	Value of $x \times 10-2R$, in degs.	Observ'd altitude.	Value of $x \times 10-2R$ in degs.	Observ'd altitude.	Value of $x \times 10-2R$, in degs.
11° 48′	0° 06′	13° 34′	16° 17′	15° 20′	33 23	17° 06′	54° 08′
50	0 24	36	16 35	22	33 43	08	54 37
52	0 43	38	16 54	24	34 04	10	55 05
54	1 01	40	17 13	26	34 25	12	55 34
56	1 19	42	17 31	28	34 46	14	56 03
58	1 38	44	17 50	30	35 07	16	56 33
12 00	1 56	46	18 08	32	35 28	18	57 03
02	2 14	48	18 27	34	35 49	20	57 34
04	2 32	50	18 46	36	36 10	22	58 05
06	2 51	52	19 05	38	36 31	24	58 36
08	3 09	54	19 23	40	36 53	26	59 08
10	3 27	56	19 42	42	37 14	28	59 40
12	3 45	58	20 01	44	37 35	30	60 13
14	4 04	14 00	20 20	46	37 57	32	60 46
16	4 22	02	20 38	48	38 19	34	61 20
18	4 40	04	20 57	50	38 40	36	61 54
20	4 58	06	21 16	52	39 02	38	62 29
22	5 16	08	21 35	54	39 23	40	63 05
24	5 34	10	21 54	56	39 45	42	63 42
26	5 53	12	22 13	58	40 08	44	64 19
28	6 11	14	22 32	16 00	40 31	46	64 56
30	6 30	16	22 51	02	40 53	48	65 36
32	6 48	18	23 10	04	41 16	50	66 16
34	7 06	20	23 29	06	41 38	52	66 56
36	7 25	22	23 49	08	42 01	54	67 38
38	7 43	24	24 08	10	42 24	56	68 21
40	8 01	26	24 27	12	42 47	58	69 06
42	8 19	28	24 46	14	43 10	18 00	69 52
44	8 37	30	25 06	16	43 33	02	70 40
46	8 55	32	25 25	18	43 56	04	71 29
48	9 14	34	25 44	20	44 19	06	72 22
50	9 32	36	26 03	22	44 43	08	73 17
52	9 50	38	26 23	24	45 07	10	74 11
54	10 08	40	26 43	26	45 31	12	75 15
56	10 27	42	27 02	28	45 55	14	76 22
58	10 45	44	27 22	30	46 19	16	77 32
13 00	11 03	46	27 41	32	46 43	18	78 51
02	11 22	48	28 01	34	47 08	20	80 20
04	11 41	50	28 21	36	47 33	21	81 09
06	11 59	52	28 41	38	47 58	22	82 03
08	12 17	54	29 00	40	48 23	23	83 05
10	12 35	56	29 20	42	48 48	24	84 18
12	12 54	58	29 40	44	49 13	25	85 53
14	13 12	15 00	30 00	46	49 38	26	88 47
16	13 30	02	30 20	48	50 04		
18	13 49	04	30 40	50	50 31		
20	14 07	06	31 00	52	50 57		
22	14 25	08	31 20	54	51 24		
24	14 44	10	31 40	56	51 50		
26	15 03	12	32 01	58	52 17		
28	15 21	14	32 21	17 00	52 45		
30	15 40	16	32 42	02	53 12		
32	15 58	18	33 02	04	53 40		

Limit of the Quadrant c = 18°—26′—05″.

TABLE IV, *for the Construction of the Quadrant* D. Fig. 8, Plate I.

Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.
18° 28′	0° 15′	20° 10′	13° 40′	21° 52′	27° 10′	23° 34′	41° 40′
30	0 31	12	13 55	54	27 26	36	41 58
32	0 47	14	14 11	56	27 42	38	42 16
34	1 03	16	14 27	58	27 59	40	42 35
36	1 19	18	14 42	22 00	28 15	42	42 53
38	1 35	20	14 58	02	28 31	44	43 11
40	1 51	22	15 14	04	28 47	46	43 30
42	2 07	24	15 29	06	29 04	48	43 48
44	2 23	26	15 45	08	29 20	50	44 07
46	2 39	28	16 01	10	29 36	52	44 26
48	2 55	30	16 17	12	29 53	54	44 45
50	3 11	32	16 32	14	30 10	56	45 04
52	3 27	34	16 48	16	30 26	58	45 23
54	3 42	36	17 04	18	30 43	24 00	45 42
56	3 58	38	17 20	20	31 00	02	46 01
58	4 14	40	17 35	22	31 16	04	46 21
19 00	4 29	42	17 51	24	31 33	06	46 40
02	4 45	44	18 07	26	31 49	08	46 59
04	5 01	46	18 23	28	32 06	10	47 19
06	5 17	48	18 38	30	32 23	12	47 38
08	5 33	50	18 54	32	32 40	14	47 58
10	5 48	52	19 10	34	32 57	16	48 18
12	6 04	54	19 26	36	33 13	18	48 38
14	6 20	56	19 42	38	33 30	20	48 58
16	6 36	58	19 58	40	33 47	22	49 18
18	6 51	21 00	20 13	42	34 04	24	49 39
20	7 07	02	20 29	44	34 21	26	49 59
22	7 23	04	20 45	46	34 38	28	50 20
24	7 39	06	21 01	48	34 55	30	50 40
26	7 55	08	21 17	50	35 12	32	51 00
28	8 10	10	21 33	52	35 29	34	51 21
30	8 26	12	21 49	54	35 46	36	51 43
32	8 42	14	22 05	56	36 03	38	52 04
34	8 58	16	22 20	58	36 20	40	52 26
36	9 13	18	22 36	23 00	36 38	42	52 47
38	9 29	20	22 52	02	36 55	44	53 09
40	9 45	22	23 08	04	37 12	46	53 31
42	10 00	24	23 24	06	37 30	48	53 52
44	10 16	26	23 40	08	37 48	50	54 14
46	10 31	28	23 56	10	38 05	52	54 36
48	10 47	30	24 13	12	38 23	54	54 59
50	11 03	32	24 29	14	38 40	56	55 21
52	11 18	34	24 45	16	38 58	58	55 44
54	11 34	36	25 00	18	39 15	25 00	56 08
56	11 50	38	25 16	20	39 33	02	56 31
58	12 06	40	25 32	22	39 52	04	56 54
20 00	12 21	42	25 49	24	40 09	06	57 17
02	12 37	44	26 05	26	40 27	08	57 41
04	12 53	46	26 21	28	40 45	10	58 05
06	13 08	48	26 37	30	41 03	12	58 29
08	13 24	50	26 53	32	41 22	14	58 54

TABLE IV, *Continued.*

Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3R$, in degs.
25° 16′	59° 19′	25° 38′	64° 12′	26° 00′	70° 03′	26° 22′	78° 16′
18	59 44	40	64 41	02	70 40	24	79 18
20	60 09	42	65 10	04	71 17	26	80 26
22	60 35	44	65 40	06	71 56	28	81 46
24	61 00	46	66 11	08	72 37	29	82 27
26	61 26	48	66 42	10	73 18	30	83 19
28	61 53	50	67 13	12	74 03	31	84 13
30	62 20	52	67 46	14	74 48	32	85 20
32	62 47	54	68 19	16	75 35	33	86 47
34	63 15	56	68 53	18	76 25		
36	63 44	58	69 27	20	77 18		

Limit of the Quadrant D=26° 33′ 41″.

In order to obtain a result with these quadrants, which can approximate to less than *a tenth of an unit* it will be necessary to make the *radius* of each quadrant of *about six inches.*

In tracing these quadrants on both sides of a sheet of paste-board a complete set will require only two sheets.

It may happen that in the course of a topographical survey some distances have been measured with a chain according to the inclination of the ground ; in that case the formula for computing an altitude would be

$$h = l \sin \delta \quad . \quad . \quad (12)$$

and quadrants could be made on a principle similar to the above mentioned.

VI. *Diagram for reducing to the horizon any distance given by the Stadia, with correction for its verticality.*

The formula used for computing with the table of logarithms is (6); but for *graphical* computation the formula (7) is preferred.

Principle : The versed sine of an arc corresponding to the expression $\sin^2 \delta$ being found from the table of logarithms, its value in number is increased *one thousand times*, from 0° to 1° 50′; *one hundred times* from 1° 50′ to 5° 45′; and *ten times* from 5° 45′ to 23°. This being the limit of the diagrams, for it is very seldom that so great an altitude as 23° be taken in topography, on account of the discrepancy which observations with such a slope would produce.

In order to avoid a confusion of lines, a diagram is made for each series or multiple of versed sine.

Construction of a diagram: Fig. 9, Pl. I. Draw a line A B of any given length (six inches), and from its extremities A and B trace the lines A D, B C at right angles to it. Divide each of the lines A D and B C in the same number of equal parts (say twenty parts to one inch) and draw from each division parallel lines as C D, E F, G H, &c.

The line A B being taken as a radius or an unit, make a *scale of versed sines* on the line B C and draw lines from A to each extremity of versed sine as A I, A K, A L, &c.; this done the diagram for the reduction to the horizon is complete.

Now to make use of the diagram; suppose a distance M N corresponding to a certain altitude which is represented by the angle B A K, its versed sine will be N O, for it is obvious that the versed sine is found by comparing together the similar triangles K A B and N A O; A O being equal to M N.

The value of the versed sine increased *one thousand times* will make the first diagram, or diagram A; the versed sine multiplied by *one hundred* will give the diagram B; and the versed sine multipled by *ten* will compose the diagram C.

Consequently the versed sine N O will be *one thousand*, or *one hundred* or *ten times* greater according to which series of diagrams it belongs to; and using a general expression, by calling the distance M N $=l$, and the versed sine N O $=x$, the reduction to the horizon of any distance will be

$l-x\times 0{\cdot}001$	for any	versed sine	contained in the	diagram A;
$l-x\times 0{\cdot}01$	"	"	"	diagram B;
$l-x\times 0{\cdot}1$	"	"	"	diagram C;

The diagrams A and B, with a radius of about 6 inches, give a result which can approximate to a *hundredth of an unit* and the diagram C, to a *tenth of an unit*.

In tracing the diagrams (Fig 13, Pl. I) A and B on one side of a sheet of paste-board, as shown in the Fig. 13, and the diagram C on the other side of the same sheet; the three diagrams will require only one sheet.

If distances measured with a chain are to be reduced to the horizon, the formula will be

$$r = l \cos \delta \quad . \quad . \quad . \quad (13)$$

and diagrams can be made on the same principle as the one above mentioned.

It results from these explanations on the Stadia, that a telescope adjusted with a micrometer having a movable wire, cannot give an exact distance, unless the staff used as *Stadia* be always set up in a normal position in regard to the axis of the telescope.

The following Tables contain the value of versed sine corresponding to each series of these diagrams.

TABLE V, *for the Diagram* A. Fig. 10, Plate I.

Observ'd altitude.	Value of $x \times 1000$.	Observ'd altitude.	Value of $x \times 1000$.	Observ'd altitude.	Value of $x \times 1000$.	Observ'd altitude.	Value of $x \times 1000$.
0° 02′	·0005	0° 30′	·0761	0° 58′	·2846	1° 26′	·6257
04	·0014	32	·0876	1 00	·3048	28	·6550
06	·0033	34	·0977	02	·3251	30	·6850
08	·0056	36	·1095	04	·3468	32	·7158
10	·0084	38	·1220	06	·3684	34	·7477
12	·0120	40	·1354	08	·3904	36	·7798
14	·0166	42	·1430	10	·4144	38	·8125
16	·0216	44	·1620	12	·4389	40	·8460
18	·0277	46	·1791	14	·4630	42	·8802
20	·0336	48	·1948	16	·4884	44	·9150
22	·0409	50	·2114	18	·5148	46	·9505
24	·0488	52	·2288	20	·5414	48	·9868
26	·0570	54	·2468	22	·5691	50	1·0236
28	·0663	56	·2653	24	·5970		

The altitude 1° 50′ is the limit of the Diagram A.

TABLE VI, *for the Diagram* B. Fig. 11, Plate I.

Observ'd altitude.	Value of $x \times 100$.	Observ'd altitude.	Value of $x \times 100$.	Observ'd altitude.	Value of $x \times 100$.	Observ'd altitude.	Value of $x \times 100$.
1° 50′	·10236	2° 50′	·2443	3° 50′	·4465	4° 50′	·7099
55	·11184	55	·2589	55	·46657	55	·7346
2 00	·12178	3 00	·2739	4 00	·4866	5 00	·7596
05	·13218	05	·2893	05	·5070	05	·7850
10	·14293	10	·30514	10	·5279	10	·8109
15	·15416	15	·32143	15	·5492	15	·8373
20	·16575	20	·33809	20	·5709	20	·8639
25	·1778	25	·35516	25	·5930	25	·8911
30	·19025	30	·3727	30	·6156	30	·9187
35	·20316	35	·3906	35	·6385	35	·9464
40	·21646	40	·4089	40	·6619	40	·9749
45	·23018	45	·4277	45	·6857	45	1·0038

The altitude 5° 45′ is the limit of the Diagram B.

TABLE VII, *for the Diagram* c. Fig. 12, Plate I.

Observ'd altitude.	Value of $x \times 10$.	Observ'd altitude.	Value of $x \times 10$.	Observ'd altitude.	Value of $x \times 10$.	Observ'd altitude.	Value of $x \times 10$.
5° 45′	·10038	10° 05′	·3066	14° 25′	·6199	18° 45′	1·0332
50	·1033	10	·3116	30	·6268	50	1·0421
55	·1063	15	·3167	35	·6340	55	1·0510
6 00	·1093	20	·3218	40	·6411	19 00	1·0599
05	·1123	25	·3269	45	·6483	05	1·0689
10	·1154	30	·3321	50	.6554	10	1·0779
15	·1186	35	·3374	55	·6636	15	1·0869
20	·1217	40	·3426	15 00	·6698	20	1·0960
25	·1249	45	.3479	05	·6772	25	1·10514
30	·1282	50	·3533	10	.6845	30	1·1143
35	·1315	55	·3587	15	·6918	35	1·1234
40	·1348	11 00	·3641	20	·6993	40	1·1326
45	·1382	05	·3696	25	·7067	45	1·1418
50	·1416	10	·3751	30	·7140	50	1·15115
55	·1450	15	·3806	35	·7217	55	1·16045
7 00	·1485	20	·3862	40	·7292	20 00	1·16978
05	·1521	25	·3918	45	·7368	05	1·17915
10	·1558	30	·3975	50	·7444	10	1·18854
15	·1593	35	·4032	55	·75207	15	1·19798
20	·1630	40	·4089	16 00	·7598	20	1·2074
25	·1667	45	·4147	05	·7675	25	1·2169
30	·1705	50	·4206	10	·7753	30	1·2265
35	·1742	55	·4264	15	·7831	35	1·2360
40	·1778	12 00	·4323	20	·7909	40	1·2456
45	·1819	05	·4382	25	·7987	45	1·2552
50	·1858	10	·4442	30	·8066	50	1·2649
55	·1897	15	·4502	35	·8146	55	1·2745
8 00	·1937	20	.4563	40	·8225	21 00	1·2843
05	·1977	25	·4623	45	·8306	05	1·2940
10	·2018	30	.4685	50	·8386	10	1·3038
15	·2059	35	·4747	55	·8467	15	1·3136
20	·2101	40	·4808	17 00	·8548	20	1·3234
25	·2143	45	·4871	05	·8629	25	1·3333
30	·2185	50	·4934	10	·87115	30	1·3432
35	·2228	55	·4997	15	·8794	35	1·3532
40	·22705	13 00	·5061	20	·8876	40	1·3631
45	·2314	05	·5124	25	·8959	45	1·3731
50	·2358	10	·5189	30	·9042	50	1·3832
55	·2403	15	·5254	35	·9126	55	1·3932
9 00	·2448	20	·5319	40	·9210	22 00	1·4033
05	·2493	25	·5384	45	·9294	05	1·4134
10	·2538	30	·5450	50	·9379	10	1·4235
15	·2584	35	·5516	55	·9464	15	1·4337
20	·2631	40	·5582	18 00	·9549	20	1·4439
25	·2677	45	·5649	05	·9635	25	1·4540
30	·2724	50	·5717	10	·9721	30	1·4640
35	·2772	55	·5785	15	·9807	35	1·4740
40	·2820	14 00	·5853	20	·9894	40	1·4850
45	·2868	05	·5921	25	·9981	45	1·4950
50	·2917	10	·5990	30	1·0068	50	1·5058
55	·2966	15	·6059	35	1·0156	55	1·5160
10 00	·3015	20	·6129	40	1·0244	23 00	1·5267

The altitude 23° is the limit of the Diagram c.

The same case occurs when the Stadia is held horizontally; it ought to be in a normal direction to the telescope, for it could be oblique to the axis of the telescope, and still be horizontal.

When a topographical survey is executed with a plane-table, the altitudes of points observed with the vertical circle of its alidade, may be computed *graphically* by using a *scale of tangents*, from the horizontal distances determined on the plane-table sheet. The telescope of its alidade may also be adjusted for the Stadia, in case the points cannot be determined by intersections.

In leveling ground which is nearly flat, it has been found very expedient to use the Stadia together with a *self-reading* staff or rod. The Stadia gives the *distance* and the self-reading rod the *difference of level*, and thus avoids observing any altitude.

When a theodolite is used for such a leveling, the error of collimation of its vertical circle is to be ascertained, for adjusting the axis of its telescope to a horizontal plane.

A spirit-level can also be used by adjusting its telescope for the Stadia.

The same staff can be used by marking the scale of the Stadia on one side and the divisions of the self-reading staff or rod (in feet and decimals of a foot) on the other side.

DETROIT, 1864.

On the Effect of Impact, Vibratory Action, and long continued changes of Load on Wrought Iron Girders. By DR. FAIRBAIRN.

From the London Mechanics' Magazine, Nov., 1864.

The defects and break-downs which followed the first successful application of wrought iron to bridge-building led to doubts and fears on the part of engineers; and many of them contended for eight, and even ten times the heaviest load as the safe margin of strength. Others, and among them the late Mr. Brunel, fixed a lower standard; and I believe that gentleman was prepared in practice to work up to one-third or two-fifths of the ultimate strength of the weight that would break the bridge. Ultimately it was decided by the authorities of the Board of Trade, but from what data I am not informed, that no wrought iron bridge should with the heaviest load exceed a strain of 5 tons per square inch. Now on what principle this standard was established does not appear; and on application to the Board of Trade the answer is, that "The Lords Commissioners of Trade require that all future bridges for railway traffic shall not exceed a strain of 5 tons per square inch."

The requirement of 5 tons per square inch on the part of the Board of Trade is not sufficiently definite to secure in all cases the best form of construction. It is well known that the powers of resistance to strain are widely different with wrought iron, according as we apply a force of tension or compression; it is even possible so to disproportion the top and bottom areas of a wrought iron girder calculated to

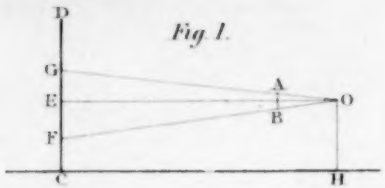


Fig. 1.

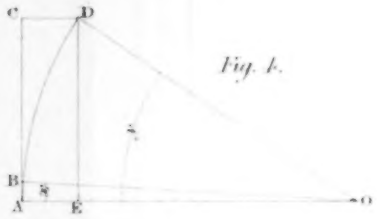


Fig. 4.

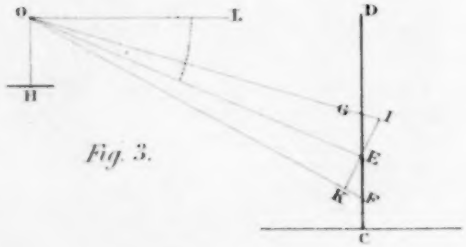


Fig. 3.

Fig. 2.

Fig. 9

Quadrant B.
$h = (v+1)0{\cdot}1\ (9)$

Fig. 6.

Scale of Versed Sines.

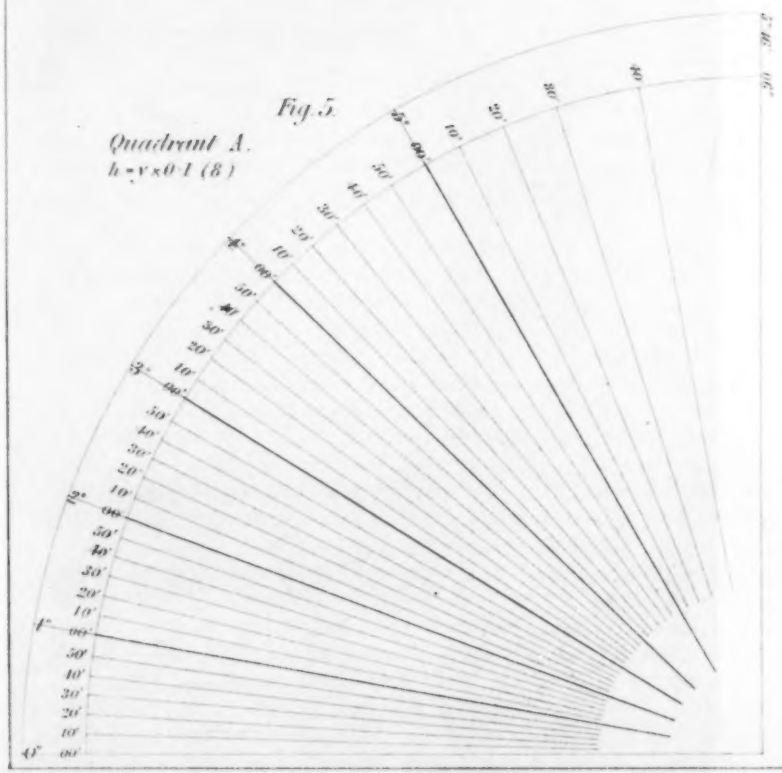


Fig. 5.

Quadrant A.
$h = v \times 0{\cdot}1\ (8)$

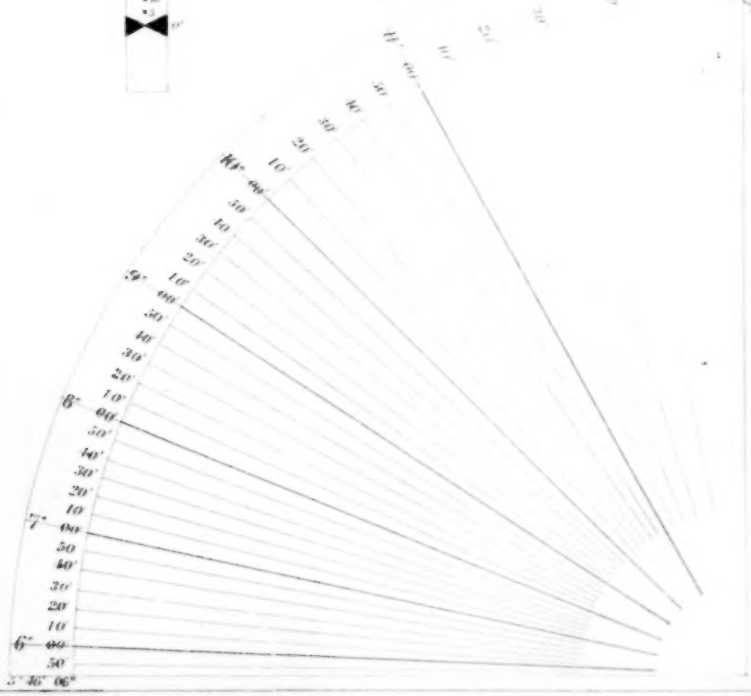


Fig. 9.

drant B.
y÷4 / 0·1 (9)
Fig. 6.

Diagram C.
x × 0·1
Fig. 12.

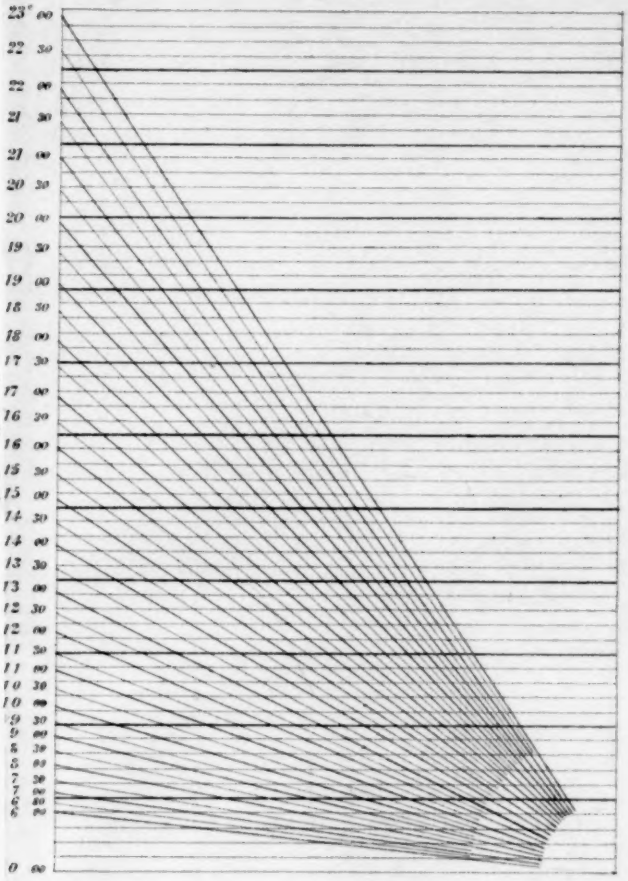


Fig. 13.

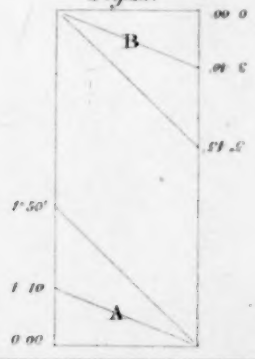


Diagram A.

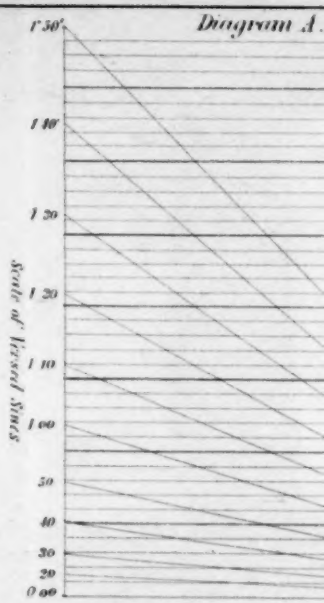


Fig. 10.

Quadrant C.
h =(y - 21) 0·1 (10)
Fig. 7.

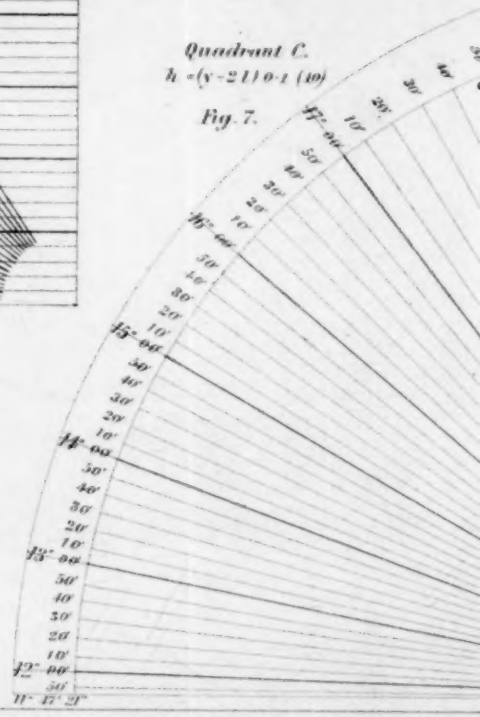


Diagram A. $x \times 0{\cdot}03$

Diagram B. $x \times 0{\cdot}01$

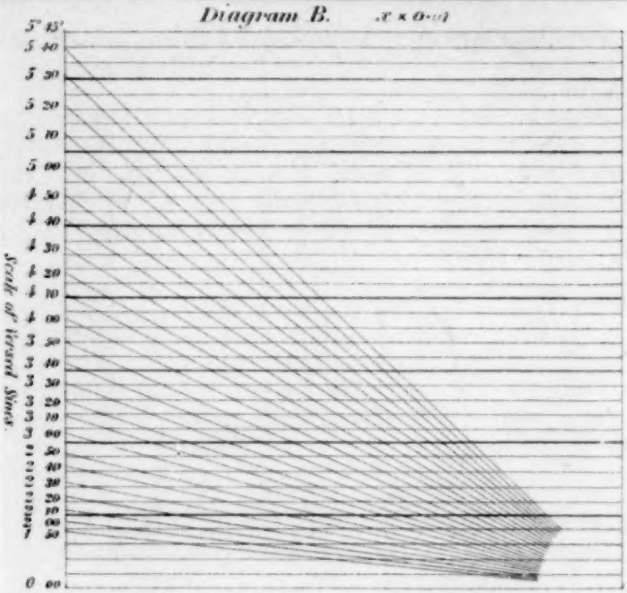
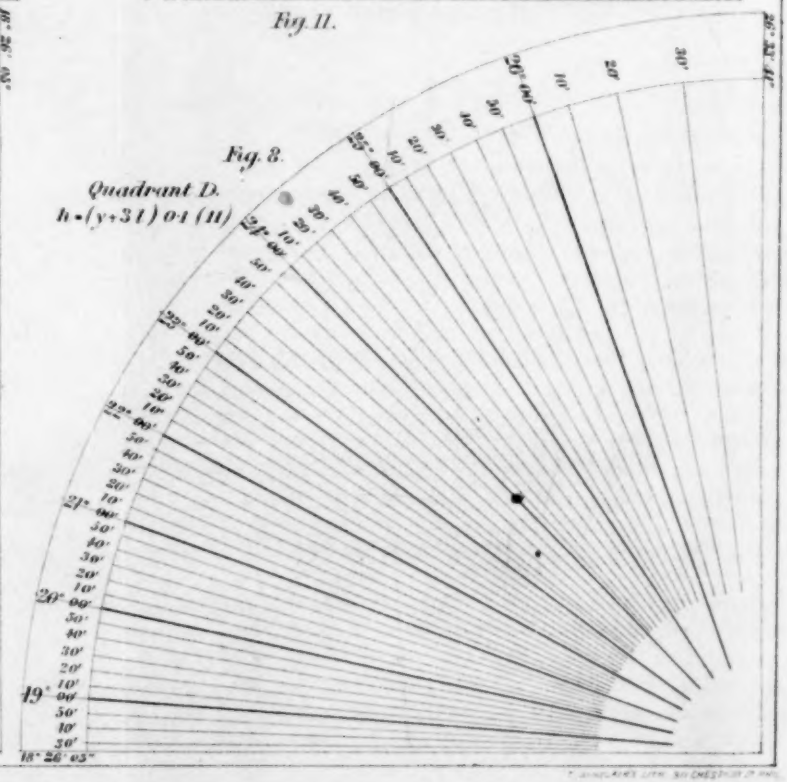


Fig. II.

Fig. 8.

Quadrant D.

$h = (y + 3t)\ 01\ (11)$



support six times the rolling load, as to cause it to yield with little more than half the ultimate strain, or ten tons on the square inch. For example, in wrought iron girders with solid tops it requires the sectional area in the top to be nearly double that of the bottom, to equalize the two forces of tension and compression; and unless these proportions are strictly adhered to in the construction, the 5-ton strain per square inch is an error which may lead to dangerous results. Again, it was ascertained from direct experiment that double the quantity of material in the top of a wrought iron girder was not the most effective form for resisting compression. On the contrary it was found that little more than half the sectional area was required, and, when converted into rectangular cells, was in its powers of resistance equivalent to double the area when formed of a solid plate. This discovery was of great value in the construction of tubes and girders of wide span, as the weight of the structure itself (which increases as the cubes, and the strength only as the squares) forms an important part of the load to which it is subjected. On this question it was evident that the requirement of the Board of Trade cannot be applied in both cases, and is therefore ambiguous as regards its application to different forms of structure. In the 5-ton per square inch there is not a word said about the dead weight of the bridge; and we are not informed whether the breaking weight was to be so many times the applied weight *plus* the multiple of the load, or, in other words, whether it included or deducted the weight of the bridge itself.

These data are wanting in the railway instructions; and until some fixed principle of construction is determined upon, accompanied by a standard measure of strength, it is in vain to look for any satisfactory result in the erection of road and railway bridges composed entirely of wrought iron.

To arrive at correct results, and to imitate as nearly as possible the strain to which bridges are subjected by the passage of heavy railway trains, an apparatus specially adapted for that purpose was designed to lower the load quickly upon the beam in the first instance, and subsequently to produce a considerable amount of vibration, as the large lever with its load and shackle was left suspended upon it in the second. The apparatus was sufficiently elastic for that purpose.

The beam tested was composed of an iron plate riveted with angle irons 22 feet long, one-eighth of an inch thick and 16 inches deep.

It was supported on two brick piers 20 feet apart. Beneath the bottom flange is fixed a lever, which, by means of a link and shackle, grasps the lower web of the beam close to the fulcrum. This fulcrum, on which the lever oscillates, is formed of a vertical bar, which acts as a standard, and has screw nuts to regulate the height from the cast iron sole plate to the fulcrum. The machinery for lifting the lever and scale consists of a shaft and pulley driven by a water-wheel; and from this shaft the apparatus for lifting the load is worked by a strap from the pulley on a pinion shaft, which drives a shaft and spur-wheel, giving motion to a connecting rod. This rod has an oblong slot at its lower end, in which the pin at the end of the lever works. From this de-

scription it will be seen that, in turning the spur-wheel, the weight is not raised until the bottom of the slot comes in contact with the pin of the lever, when the load is taken entirely off the beam. That being accomplished, the connecting rod descends, when the load is again laid upon the beam and left suspended with a vibratory motion for some seconds, until the remainder of the stroke is completed, when the connecting rod again rises for the succeeding lift. In this way the weights are lifted off and replaced alternately upon the beam at the rate of seven to eight strokes per minute. The apparatus is worked night and day by a water-wheel, and the number of changes are registered by the counter attached to the vertical post.

The girder subjected to vibration in these experiments is a wrought iron plate beam of 20 feet clear span, and of the following dimensions :—

	inches.	
Area of top, 1 plate 4 inches $\times$ $\frac{3}{8}$ inch, . .	2·00	
" 2 angle-irons 2 $\times$ 2 $\times$ 5-16ths, . .	2·30	
		4·30
Area of bottom, 1 plate 4 inches $\times$ $\frac{3}{8}$ inch, . .	1·00	
" 2 angle-irons 2 $\times$ 2 $\times$ 3-16ths inch, .	1·40	
		2·40
Web, 1 plate 15$\frac{1}{4}$ $\times$ $\frac{1}{8}$ . . .		1·90
Total sectional area, . .		8·60
Depth, ...	16 inches.	
Weight, ...	7 cwt. 3 qrs.	
Breaking weight (calculated), . . .	12 tons.	

The beam having been loaded with 6643 lbs, underwent above half-a-million changes of load, by working continuously for two months, night and day at the rate of about eight changes per minute, without producing any visible alteration, the load was increased from one-fourth to two-sevenths of the statical breaking weight, and the experiment proceeded with till the number of changes of load reached a million.

The beam had now sustained one million changes of load without any apparent injury; it was then considered necessary to increase the load to 10,486 lbs, or two-fifths of the breaking weight, when the machinery was again put in motion. With this additional weight the deflections were increased, with a permanent set of ·05 inches from ·23 to ·35, and after sustaining 5175 changes, the beam broke by tension a short distance from the middle. It is satisfactory here to observe that during the whole of the 1,005,175 changes none of the rivets were loosened or broke.

The beam was repaired by replacing the broken angle irons on each side, and putting a patch over the broken plate equal in area to the plate itself. Thus repaired, a weight of three tons was placed on the beam, equivalent to one-fourth of the breaking weight, when the experiments were again continued as before.

At the conclusion of this experiment, the beam having sustained upwards of three million changes of load without any increase of the permanent set, it was assumed that it might have continued to bear

alternate changes to any extent with the same tenacity of purpose. It was then concluded to increase the load from one-fourth to one-third of the breaking weight; and having laid on 4 tons, which increased the deflection to ·20 inches, the work was proceeded with in the same order as in the previous experiments.

From these experiments it is evident that wrought iron girders of ordinary construction are not safe when submitted to violent disturbances with a load equivalent to one-third the weight that would break them. They, however, exhibit wonderful tenacity when subjected to the same treatment with one-fourth the load; and assuming that an iron girder bridge will bear with this load 12,000,000 changes without injury, it is clear that it would require 328 years, at the rate of 100 changes per day, before its security was affected. It would, however, be dangerous to risk a load of one-third the breaking weight upon bridges of this description, as, according to the last experiments, the beam broke with 313,000 changes; or a period of eight years, at the same rate as before, would be sufficient to break it. It is more than probable that the beam might have been injured by the previous three million changes to which it had been subjected; and assuming this to be true, it would then follow that the beam was progressing to destruction, and must of necessity at some time, however remote, have terminated in fracture.

The experiments throw considerable light on this very intricate and very important subject. They are probably carried sufficiently far to enable us to state with certainty what is the safe measure of strength; and as much depends upon the quality of the material and the skill with which the girders are put together, it becomes necessary for the public safety that a measure of strength should be established without encumbering the structures with unnecessary weight. On this question it must be borne in mind that every additional ton that is not required beyond the limits of safety, is an evil that operates as a constant quantity tending to produce rupture; and hence follows the necessity of a careful distribution of the material, in order that the tube or girder shall be duly proportioned to the strains it has to bear, and that every part of the structure shall have its due proportion of work to perform.

I have assumed for the sake of illustration, that every description of material, as regards its cohesive properties, follows the same law as that which we have experimented upon, or, in other words, in the ratio of its physical powers of resistance, that is to say, the beam will follow the same law in regard to its ultimate powers of resistance, when operated upon by a corresponding load due to that power. If this be true, we have only to follow the same rule as observed in the experiments, by loading cast iron or wooden beams in the ratio of their cohesive powers of resistance, and their breaking weights respectively. This has not been proved experimentally, but I hope at some future time to have an opportunity of extending the experiments, in order to determine to what extent these views are correct.

The Lords Commissioners of Trade, in the exercise of their functions

as conservators of the public safety, have adopted the rule that no railway bridge composed of wrought iron shall exceed with its heaviest rolling load a strain of 5 tons per square inch of section upon any part of the bridge. The formula for this maximum of strain upon the material has been deduced from my own experiments on the model tube of Millwall.

Assuming the top of the girder to be sufficiently rigid to prevent buckling by compression, the formula for the strength of the bottom sections derived from these experiments is—

$$w = \frac{adc}{l},$$

where the constant $c = 80$.

Applying this formula to the beam experimented upon, we have—

a, the area of the bottom = 2·4 inches,
d, the depth of the beam = 16 inches,
c, the constant deduced from the model tube = 80,
l, the span or difference between the supports = 240 inches.

$$\text{Hence—} w = \frac{2{\cdot}4 \times 16 \times 80}{240} = 12{\cdot}8 \text{ tons},$$

the ultimate strength of the beam.

In order to determine the strain per square inch in these experiments, we find—

$$s = \frac{lw}{4ad},$$

where s represents the strain per square inch upon the section a, produced by the greatest load w, laid upon the middle of the girder.

It is necessary to observe that in a girder properly proportioned, the greatest strain per square inch will take place upon the bottom section; so that if the strain upon the bottom section of such a girder be within the Government Commissioner's condition of safety, the strain upon the top section will necessarily be within that limit also. In a girder having the cellular structure at its top section, the area of the top section should be very nearly once and a quarter that of the bottom section, or the areas of their sections should be respectively as 5 : 4; and the strain per square inch upon these parts will be respectively inversely as their areas, that is, the strain per square inch upon the top section will be four-fifths of the strain per square inch upon the bottom section. In one of the foregoing experiments, we have—

l, the length of the girder = 240 inches,
w, the weight laid on the middle = 2·96 tons,
a, the area of the bottom section = 2·4 inches,
d, the depth of the girder = 16 inches;

$$\text{therefore, } s = \frac{240 \times 2{\cdot}96}{4 \times 2{\cdot}4 \times 16} = 4{\cdot}62 \text{ tons},$$

the strain per square inch on the bottom section of the girder.

Applying this formula to the whole series of experiments, we obtain the following summary of results :—

Summary of Results.—1st Series of Experiments.
Beam 20 feet between the supports.

No. of experiment.	Date.	Weight on middle of beam in tons.	Number of changes of load.	Strain per sq. in. on bottom.	Strain per sq. in. on top.	Deflection in inches.	Remarks.
1	From March 21st to May 14th, 1860,	2·96	596,790	4·62	2·58	·17	
2	From May 14th to June 26th, 1860,	3·50	403,210	5·46	3·05	·23	
3	From July 25th to July 28th, 1860,	4·68	5,175	7·31	4·08	·35	Broke by tension at a short distance from the centre of the beam.

The number of 1,005,175 changes was attained before fracture, with varying strains upon the bottom flange of 4·62 tons, 5·46 tons, and 7·31 tons per square inch.

Beam repaired.—2d Series of Experiments.

4	August 9th, 1860, .	4·68	158	7·31	4·08	. .	The apparatus was accidentally set in motion.
5	August 11th and 12th,	3·58	25,742	5·59	3·12	·22	
6	From August 13th, 1860, to October 16th, 1861, .	2·96	3,124,100	4·62	2·58	·18	
7	From October 18th, 1861, to January 9th, 1862, . .	4·00	313,000	6·25	3·48	·20	Broke by tension as before, close to the plate riveted over the previous fracture.

Here the number of 3,463,000 changes was attained when fracture ensued.

From the above it is evident that wrought iron girders, when loaded to the extent of a tensile strain of seven tons per square inch, are not safe, if that strain is subjected to alternate changes of taking off the load and laying it on again, provided a certain amount of vibration is produced by that process; and what important to notice is, that from 300,000 to 400,000 changes of this description are sufficient to ensure fracture. It must, however, be borne in mind that the beam from which these conclusions are derived had sustained upwards of 3,000,000 changes with nearly five tons tensile strain on the square inch, and it must be admitted from the experiments thus recorded that five tons per square inch of tensile strain on the bottom of girders, as fixed by the Board of Trade, appears to be an ample standard of strength.

As regards compression, we have only to compare for practical purposes the difference between the resisting powers of the material to tension and compression, and we shall require in a girder without a

cellular top from one-third to three-fourths more material to resist compression than to resist tension; and as the strength of wrought iron in a state of compression is to its strength in a state of tension as about 3 to 4½, the area of the top and bottom will be nearly in that proportion, or, in other words, it will require that much more material in the top than the bottom to equalize the two forces.

In the experimental beam the area of the top was considerably in excess of that of the bottom, it having been constructed on data deduced from the experiments on tubes without cells, which required nearly double the area on the top to resist crushing. In the construction of large girders, where thicker plates are used, this proportion no longer exists, as much greater rigidity is obtained in the thicker plates, which causes a closer approximation to equal areas in the top and bottom of the girder; and from this we deduce that from one-third to three-fourths, and in some cases one-third additional area in the top, has been found according to the size of the girder, sufficient to balance the two forces under strain.

The foregoing experiments, however, were instituted to determine the safe measure of strength as respects tension, and it will be seen that in no case during the whole of the experiments was there any appearance of the top yielding to compression.

For the Journal of the Franklin Institute.

The Radial Paddle-Wheel. By JOHN D. VAN BUREN, Jr., C. E. U. S. Naval Engineers.

Proposition. To find the centre of dynamic resistence of a radial paddle-wheel propelling a vessel through the water.

Notation.

Let $R_2 = CR_2$ = distance from centre of shaft to outer line of paddles.

$R_1 = CR_1$ = " " inner "

$x = Cx$ = " " centre of normal resistance of paddle $R_1 R_2$

w = angular velocity of paddle-wheel.

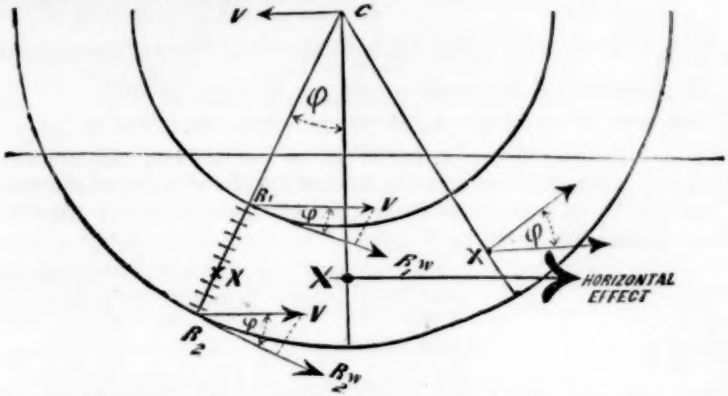
v = actual velocity of vessel through the water.

φ = angle made by CR_2 with the vertical.

Let us suppose, that instead of the vessel being propelled through the water while the wheel turns ahead, the water has a current from bow to stern of v. This supposition does not affect the conditions of the problem.

The area of the paddle may be considered made up of indefinately small rectangular areas, the length of each being the length of the paddles, which will be considered equal to 1, since the *length* of the paddle does not influence the distance from the centre of the shaft to the centre of resistance. The breadth or depth of any one of these elementary areas may be represented by the *differential* of its dis-

tance from the centre of the shaft, or dr, where r equals that distance. The length being 1, the area is dr.



Now the accepted law of fluid resistance is: The resistance opposed to the motion of any body through a fluid varies with the square of the velocity. In this case the velocity which is effective in producing the resistance to the motion of any one of these elementary areas, dr, through the water, is the difference between the velocity of rotation of this area and that component of the velocity of the current which is normal to the face of the paddle, since the water flows away from the paddle with that component velocity. Therefore for any elementary area dr, we shall have for the velocity effective in producing resistance

$$r w - v \cos \varphi \quad . \quad . \quad . \quad (1)$$

Now calling the resistance per unit of surface, unity, at that point where the velocity effective in producing resistance is 1 (which we are at liberty to do, since the unit of resistance is arbitrary), we have for the resistance of dr at a distance r from c.

$$(r w - v \cos \varphi)^2 \, dr \quad . \quad . \quad . \quad (2)$$

The total resistance for the paddle is therefore

$$\int_{R_1}^{R_2} (r w - v \cos \varphi)^2 \, dr \quad . \quad . \quad . \quad (3)$$

But the moments of the components summed equals the moment of the resultant; hence

$$x \int_{R_1}^{R_2} (r w - v \cos \varphi)^2 \, dr = \int_{R_1}^{R_2} (r w - v \cos \varphi)^2 \, r dr \quad . \quad (4)$$

$$\therefore x = \frac{\int_{R_1}^{R_2} (r w - v \cos \varphi)^2 \, r dr}{\int_{R^1}^{R_2} (r w - v \cos \varphi)^2 \, dr} \quad . \quad . \quad . \quad (5)$$

Integrating between limits

$$x = \frac{\frac{1}{4}(R_2^4 - R_1^4)w^2 - \frac{2}{3}(R_2^3 - R_1^3)wv\cos\varphi + \frac{1}{2}(R_2^2 - R_1^2)v^2\cos^2\varphi}{\frac{1}{3w}(R_2 w - v\cos\varphi)^3 - \frac{1}{3w}(R_1 w - v\cos\varphi)^3}$$

Clearing of fractional co-efficients and expanding terms of denominator,

$$x = \frac{3(R_2^4 - R_1^4)w^2 - 8(R_2^3 - R_1^3)wv\cos\varphi + 6(R_2^2 - R_1^2)v^2\cos^2\varphi.}{4(R_2^3 - R_1^3)w^2 - 12(R_2^2 - R_1^2)wv\cos\varphi + 12(R_2 - R_1)v^2\cos^2\varphi} \qquad (6)$$

Let n = number of revolutions of wheel per minute, and $v = mR_2 w$ where m = a fraction representing the ratio of the velocity of the vessel to the velocity of rotation of outer circumference of wheel; then $w = 2\pi n$. These substituted in (6) give

$$x = \frac{3(R_2^4 - R_1^4) - 8(R_2^3 - R_1^3)R_2 m\cos\varphi + 6(R_2^2 - R_1^2)R_2^2 m^2\cos^2\varphi}{4(R_2^3 - R_1^3) - 12(R_2^2 - R_1^2)R_2 m\cos\varphi + 12(R_2 - R_1)R_2^2 m^2\cos^2\varphi}.$$

Putting $R_1 = pR_2$, there finally results

$$x = R_2 \cdot \frac{3(1-p^4) - 8(1-p^3)m\cos\varphi + 6(1-p^2)m^2\cos^2\varphi}{4(1-p^3) - 12(1-p^2)m\cos\varphi + 12(1-p)m^2\cos^2\varphi}. \qquad (7)$$

which gives the distance from the centre of the shaft to centre of resistance of the paddle which makes an angle φ with the vertical.

If any of the paddles are not wholly immersed, then, in calculating (7) p must be so altered as to make the distance from the centre of the shaft to the water line of said paddle $R_1' = pR_2$.

If in (7) we make $m = o$, the value of x becomes

$$x = \tfrac{3}{4}R_2 \cdot \frac{(1-p^4)}{(1-p^3)} \qquad . \qquad . \qquad . \qquad (8)$$

In this case the vessel does not move, and it answers the case of a vessel moored where there is no current. It will be observed this value of x is entirely independent of ϕ, as it evidently should be, and the centres of resistance of all the paddles will therefore be situated in the same circle. If in addition to this p, or $R_1 = o$, we shall have the wheel immersed to its centre and the breadth of the paddle $= R_2$; and for this case

$$x = \tfrac{3}{4}R_2 \qquad . \qquad . \qquad . \qquad . \qquad (9)$$

or, in other words, in a rectangular board, with one of its edges in the surface of the water, and made to rotate about that edge, the centre of resistance is at a distance of three-fourths of the depth of the board from that edge.

EXAMPLE. Let $R_1 = \cdot 8\ R_2$ or $p = \cdot 8$. Suppose there are five paddles immersed, the upper ones only half submerged. Let $m = \cdot 8$, or $v = \cdot 8\ R_2\ w$, *i. e.* slip = 20 per cent. Let $\varphi_1 = \varphi_5 = 60°$, $\varphi_2 = \varphi_4 = 30°$ $\varphi_3 = 0°$.

Now for the two upper paddles, $p = \cdot 9$, we have

$3(1-p^4) = 3(1-\cdot 9^4) = 1\cdot 032$, $8(1-p^3) = 8(1-\cdot 9^3) = 2\cdot 168$,

$6(1-p^2) = 6(1-\cdot 9^2) = 1\cdot 14$, $m\cos\varphi_1 = \cdot 8 \times \cdot 5 = \cdot 4$, $m^2\cos^2\varphi_1 \cdot 64 \times \cdot 25 = \cdot 16$

$4(1-p^3) = 4(1-\cdot 9^3) = 1\cdot 084$, $12(1-p^2) = 12(1-9^2) = 2\cdot 28$,

$12(1-p) = 12(1-\cdot 9) = 1\cdot 2$

$\therefore$ $*N_1=N_5=3(1-p^4)-8(1-p^3)\,m\cos\phi+6(1-p^2)m^2\cos^2\phi=\cdot3468$

$*D_1=D_5=4(1-p^3)-12(1-p^2)m\cos\phi+12(1-p)m^2\cos\phi=\cdot3640$

To find $N_2=N_4$, and $D_2=D_4$,

$3(1-\cdot8^4)=1\cdot7712$, $8(1-\cdot8^3)=3\cdot9040$, $6(1-\cdot8^2)=2\cdot16$

$m\cos\varphi_2=\cdot4-\sqrt{\cdot3}=\cdot6928$, $m^2\cos^2\varphi_2=\cdot48$

$4(1-\cdot8^3)=1\cdot952$, $12(1-\cdot8^2)=4\cdot32$, $12(1-\cdot8)=2\cdot4$

$\therefore$ $N_2=N_4=\cdot1033$

$D_2=D_4=\cdot1111$

($\cos\varphi_3=1$) $N_3=\cdot0304$

$D_3=\cdot0320$

From (7) we obtain for the distance from centre of shaft to centre of resistance of the different paddles:

Corresponding to ϕ_1, and ϕ_5, half submerged,

$$X=\frac{3468}{3640}R_2=\cdot953\,R_2$$

Corresponding to ϕ_2 and ϕ_4,

$$X=\frac{\cdot1033}{1111}R_2=\cdot93\,R_2$$

Corresponding to ϕ_3,

$$X=\frac{304}{320}R_2=\cdot95\,R_2$$

* D Denominator, and N Numerator of (7).

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

Remarkable Plumb-Line Deflection at Cowhythe.

From the London Mechanics' Magazine, October, 1864.

We are enabled to furnish our readers with the following particulars respecting a curious local disturbance of the plumb-line in the neighborhood of Cowhythe, which is now the subject of research, with the view to its being traced on its limit, by a party of the Royal Engineers, under Colonel Sir Henry James, R.E., F.R.S., &c., superintendent of the Ordnance Surveys. Early during the present century, the headland eastward of Portsoy on Cowhythe was visited by an officer of the Royal Engineers with the zenith sector, constructed for the Ordnance Survey of this country by the celebrated Ramsden, and from the observations made with that instrument to determine the latitude of the trigonometrical station there, it was found that the plumb-line, instead of being vertical, was deflected northward of the zenith and southward of the earth's centre, fully nine seconds of angular measure. This extraordinary and unexpected result was viewed with great interest by the scientific world, especially by such as were employed by their respective Governments in connexion with the determination of the figure of the earth; and, by way of verification, a party of the same corps, some sixteen years back, furnished with a new zenith sector,

designed by the present Astronomer Royal, and constructed by Troughton and Sims, visited the same spot. More observations, and to a greater number of stars, resulted in confirming the first or earlier determination; and here the matter rested, merely as a subject of occasional wonder to those concerned, till recently the Russian engineers, in prosecution of their national survey, came upon a similar anomaly in the neighborhood of their ancient capital, Moscow. On tracing it to its limit, which they have done in a public-spirited and most creditable manner, they concluded that there is a vacuum, or a comparative vacuum, of a great many square miles in extent, under the earth's surface in that country. To give some idea of the reasoning which leads to so startling a conclusion, the reader may conceive a wide, deep pit with a plummet suspended from its mouth at the earth's surface. The plumb-line will be vertical only when in the centre of the pit (or shaft, as it is called in connexion with mines), because it will there be equally attracted in every direction. If carried round the side of the pit, the line will be so deflected from the vertical as to cause all the lines, if produced upward, to meet in a point above the earth's surface; and such are the phenomena discovered by the geoditical engineers of Russia. The pit, it is true, is closed at its mouth, and no plumb-line can be let down into it, but the spirit-level, being always at right-angles to the plumb-line, discloses the fact as clearly to the mind as the open pit would to the eye. Now, whether the Cowhythe deflection is to be accounted for by a comparative vacuum on the north under the Moray Firth, or by some unknown mass of extraordinary density on the south, or partly by both, is the problem to be solved, and doubtless it will ultimately be solved by the thoroughly trained staff of astronomical observers and computors under their talented chief, Sir Henry James. Their present operations with zenith telescopes, transits, chronometers, theodolites, &c., were commenced at Cowhythe in August, and are now extended, according to the *Banffshire Journal*, southward to the Fourman Hill, near Rothiemay, and Westerfield (formerly known as the Haggs), near Inverkeithny, all in Banffshire where our Highland tourists may see the parties regularly encamped, with their portable observatories and instruments all in working order. The general result can be but briefly stated to be a diminution of the deflection as the observers proceed southwards, but how far it may extend is of course at present unknown.

A Useful Pack-Saddle.

From the London Mechanics' Magazine, November, 1864.

Lieutenant D. M'Mahon, 1st battalion Military Train, has invented and brought into complete working order a most useful species of pack-saddle, adapted to the capacity of horses and mules of various sizes and burdens. By a simple contrivance of turning an inverted screw in the upper part of the frame-work, the saddle is brought to fit the back of any ordinary horse or mule, and is enlarged or rendered suitable to smaller animals as required. The invention has been tested successfully at Woolwich.

For the Journal of the Franklin Institute.

Work and Vis-viva. By De Volson Wood, Prof. of C. E., University of Michigan.

I have just read the article "On the Elements of Physical Work, &c." by J. W. Nystrom, which is published in the November number of the Journal. I regret to find so many errors in an article which possesses so much merit both in the original manner in which the subject is presented, and in the apt illustrations which accompany his analysis. The geometrical magnitudes used to illustrate his ideas of force, power, and work, struck me very forcibly, and I think they will ever be found serviceable in impressing upon the mind the truths which he has presented.

But I have intimated that there are errors in the article; and it is my present purpose to note them, and not to write a review of the article; and as he comes before us as a truth-seeker, I doubt not he will kindly receive any criticism which may be passed upon it.

If the terms which he uses, as *force*, *work*, *power*, *vis-viva*, &c., are definitions or the names of algebraic expressions, we have only to consider the propriety of their use; but if the terms or phrases involve principles, they must stand the test of analysis.

For instance; if "power," is *defined* to be "the product of the force by the velocity;" or "work," to be "the continued product of the force, velocity, and time;" or vis-viva, to be "the product of mass by the square of the velocity," we have only to consider the propriety of their use; to see if they agree with the terms which have long been used to express the same idea, and if not to see if his terms are better than those used; or if they are new, to see if they are good terms for expressing the ideas intended. Now suppose that we have accepted the definitions which have just been indicated, and that it be asserted that work equals the vis-viva; or $F\,V\,T = M\,V^2$. Now this cannot be *assumed* or *defined*, but it must be capable of proof if it be true. I will observe that the equation is true when the force is constant and the body free to move, in which case we have $F\,T = M\,V$, also from the law of falling bodies $V = g\,T$, which in the preceding gives $F = M\,g$ = weight of the body. It must be observed that I admitted the above equality merely for the sake of the argument, and, that I may not be misunderstood, I will state that the first member, $F\,V\,T$, *does not express the work which the force* F *does upon a body free to move in producing a velocity* V, *in time* T, *but when the body is free to move, as here supposed, it equals one-half the work*, as may be shown hereafter. If it be said, for the sake of the argument, that F is constant and is operating upon a body which offers a constant resistance so that V is also constant, then I say that $F\,V\,T$ cannot equal $M\,V^2$; for we have $F\,V\,T = M\,V^2$ or $F\,T = M\,V$; but in this equation all the quantities are constant except T, hence the equation is not true. If, still further, we admit that $F\,T = s$, and $V^2 = 2\,g\,s$, we have by substitution and reduction, $F = 2\,W$, which cannot be true. We see then that the equation, $F\,V\,T = M\,V^2$, reduces to an absurdity under every hypothe-

sis except the first, and in that it simply gives a true equation without expressing the value of the work. We see then that *it never expresses the true relation between work and vis-viva.*

I have taken more space for this hypothetical case, than I intended to, and yet it will be observed that it is exactly the expression which Mr. Nystrom has given us on pages 326 and 327, vol. xlviii.

But let us notice more specifically some of the statements. The writer says, p. 326, "work appears to be the most confused function in physics," and among other things has been called "vis-viva, living force, power, momentum, &c." I can hardly conceive what class of authors the writer has had access to; for I have yet to find the author —Nystrom excepted—who considers that work means the same as any of the terms above named. It is true that work is known by many terms: for instance, Smeaton called it *mechanical power*; Carnot, moment of activity; Monge and others, *dynamic effect*; M. Navier, *quantity of action*; Poncelet, *quantity of work*; and by most modern writers, simply, *work*. On page 358, he calls F V, or as he gives it in a few lines after, M V, *moment of inertia*, while all other writers call it *momentum*; and $\Sigma\, m\, r^2$ is called moment of inertia. I fail to find where "Mosley calls work, 'moment of inertia'" (see p. 359). He says "S=V T" (see p. 326) which is true when V is constant, and yet in deducing the expression $\frac{M\, V^2}{g}$ (p. 358) he marks $T=\frac{V}{g}$, in which V is variable and increases with the time.

He says, p. 358, that the weight of the moving body at the surface of the earth where $g=32{\cdot}166$, is equal to its mass; whereas, mechanical writers say that the weight equals the mass at the point where $g=1$. Surely if "the difference between force, power, and work, appears not to be generally understood," this is making confusion worse confounded.

I have not made these criticisms in a captious spirit, but rather to help those who read from falling into the same errors.

If Mr. Nystrom has used any expression inadvertently, I hope I have not used it to his disadvantage.

I shall neglect the more agreeable part of my duty, if I do not show the true values and relations of work and vis-viva. I published an article in the November number of the Journal for 1862, and another in the February number for 1864, in which I endeavored to explain their meaning and relation, but as those articles may not be available to the readers of this, I shall make no further reference to them.

Work is overcoming resistance. If the resistance overcome is the inertia of a body, the work is called, *work of inertia*; but the work which has been done upon a body free to move, and which is stored in it, is rarely referred to in this way. It is generally referred to in terms of the vis-viva. The work commonly referred to is that of overcoming physical resistance; and if the resistance be constant and equal F, the work = F S; if F be variable the work is $\int F\, d\, s$. The ex-

pression F *s*, is, I think the primitive formula, not F V T as given on page 327. Now the work done in the space *s*, is the same whether it be done in one hour, day, or week, it is independent of the time. But if we wish to compare the *efficiency* of machines we must observe the *time* which it takes the different machines to do the same amount of work; then will their efficiencies be inversely as their times of doing the work. It is for this reason that time appears in the English unit of work which is, 33,000 lbs. raised one foot per *minute*. A force may be doing a work of resistance and of inertia at the same time, and the expression $\Sigma P\,ds$ shows how many pounds feet it has overcome and the expression $\frac{1}{2} M V^2$, how many pounds feet of resistance the moving body is capable of overcoming in being brought to rest. The latter statement requires proof. For this we will suppose that the resistance overcome is constant and equal P; and that it is overcome for a space S. From mechanics we know that the acceleration due to a force, is the force divided by the mass, or $\frac{P}{M}$. We also know that the square of the velocity equals twice the acceleration multiplied by the space, or $V^2 = 2\frac{P}{M}s$; from which we immediately find $\frac{1}{2} M V^2 = P S$ and as the latter is the work, the former must be also, and hence equals *one-half of the vis-viva.*

This may be proved quite as satisfactorily in a more elementary way. For, the work done may always be made equivalent to a weight W raised to a proper height *h*. The work of doing this will be W *h*. Now if this weight be permitted to fall freely through the height *h*, it will acquire a velocity V, and the amount of work stored in the mass must equal W *h*. But from the law of falling bodies we have $h = \frac{V^2}{2g}$ hence, we have $W h = W\frac{V^2}{2g} = \frac{1}{2} M V^2$, as before. I might illustrate these principles by numerous examples, and deduce the expression for vis-viva by different processes, but I trust I have given enough to establish my position. This is all I wish to do at present, but if it seems advisable I may refer to the subject at a future time.

The writer says on p. 359, "that the subject is nowhere properly explained." I confess that much obscurity has hung over the subject principally on account of the brevity of treatment by most authors, but I am pleased to refer your readers to "Morin's Mechanics," as translated by Joseph Bennett, and published by D. Appleton & Co. for a good exposition of the subject. For accuracy, simplicity, and thoroughness, on this subject, it is unequalled by any work within my knowledge. Whewhell in his "Mechanics and Engineering" gives a good exposition of it, and applies the principles of vis-viva to a higher class of problems, than Morin does.

While all standard writers agree upon the terms used in these ar-

ticles, yet few pretend to define "power." With its present vague meaning it should not be considered a *scientific* term, but if we agree upon the definition given by Mr. Nystrom, it will be as specific as any other term used in science. Morin, in the work above referred to, says, p. 12, "we use the words *power* and *resistance* to denote those forces which favor motion, or those which oppose it;" while the general meaning is, *ability* to do something. We speak of water-power, horse-power, steam-power, power of a lens, power of the wind, mechanical powers, physical power, moral power, and many other abilities, without any idea of the measure of those abilities. It would be a decided gain to physics if it had a specific meaning, and the term force substituted for power in those indefinite expressions.

On the Incrustation of Marine Boilers. By Mr. JAMES R. NAPIER.

From the London Mechanics' Magazine, November, 1864.

Read before the Institution of Engineers in Scotland, February 17, 1864.

In the Transactions of this Institution, 1859,60, will be found a paper which I wrote, chiefly for the purpose of showing that regenerators, as ordinarily constructed, were much too small for the object intended. But I have there also stated (page 46) that "when these regenerators are made with a sufficient amount of surface, so that abundance of water can be supplied to and discharged from the boilers with little loss of heat, then there will be *no incrustations*," &c. In the last paragraph of the paper I have, with more caution, said, "that this amount of discharge and surface, *it is expected*, will prevent incrustation, and save nine-tenths of the heat at present lost by the ordinary method of blowing off."

The object of the present communication is to show that the practice here recommended leads to results the very opposite of what was expected. Believing, as I then did, in the ordinary theory of blowing off from the boiler before the water became saturated with salts, that an abundant feed and blow-off would prevent the lime depositing, and therefore prevent the incrustations; and being desirous of saving the heat which would otherwise be lost by the great amount of blow-off which I believed to be necessary, I had a regenerator made for the S.S. "Lancefield" with about ten times the surface which it had been customary to give to such apparatus; but the results, as stated at a recent meeting, were so much at variance with my understanding of the ordinary theory, that I think a statement of the facts will help others to a clearer knowledge of the matter.

The vessel then, sailed from Glasgow about noon every Thursday for the Hebrides, lay in one of the lochs there from Saturday evening till Monday morning, and arrived again in Glasgow on Wednesday, to recommence on Thursday a similar voyage. The steam was up or at hand all the voyage; about fifteen stops, of two or three hours each, were made each week, during which time the boiler was supplied with feed by a Giffard's injector, but little or no blow-off.

While steaming, however, the quantity of water continually discharged through the regenerator was so great that the glass hydrometer used for ascertaining the density showed very little difference between the sea and the boiler-water. The boiler was worked in this manner for about four weeks, and then examined; when, instead of being found, as I expected, clean, with little or no scale or deposit, the coating was much thicker, than usual, but soft, very much like newly made mortar, not difficult, before getting dried, to scrape off all accessible places, but which when dry was nearly as difficult of removal as the ordinary compact scale.

During one of the voyages, when I was personally directing the experiment, and had for some time been keeping the greatest amount of feed on the boiler which the engine could supply, I observed the water in the gauge-glass get muddy, but did not then discover the cause. About two years before this I found the same soft limy deposit in the S. S. "Islesman's" boiler, when trying similar experiments on the same station; but as I had disregarded the "Islesman's" experience, and did not then know the experience of others, the "Lancefield's" regenerator was continued, but with lesser quantities of feed and discharge, for about six months, when the tubes of the apparatus giving way, it was discontinued. I was fortunately saved further trouble, and the expense of repairing it, by discovering in the *Annales des Mines* for 1854, an interesting paper by M. Cousté, "On the Incrustations of Boilers." He there shows that the sulphate of lime can be deposited by heat alone, without any evaporation, and that at a temperature of 124°, cent., or two atmospheres of pressure, sea-water in its natural state is very near the point of saturation. As the "Lancefield's" boiler was loaded to nearly 40 lbs of absolute pressure, and worked generally to about two atmospheres, or 255° Fahr., or about the point of saturation of the lime, it is clear that the greater the amount of sea-water supplied to the boiler, the greater would be the quantity of lime deposited in it. And although there was a constant discharge from the surface by a conical tube, only some of the deposited matter—that which had not attached itself to the boiler—could be so discharged. If this be not the true explanation of the deposit in the "Lancefield's" boiler, of the difficulty of working boilers with sea-water at higher pressures, and of the ordinary experience that boilers are cleaner when worked at a greater density, it will remain for others to explain it.

M. Cousté's experiments, however, appear to me to be conclusive. He suggests a method of getting quit of the lime by filtration at a high temperature. The following extract from his paper shows the conclusions he arrived at from his experiments:—

1. The sulphate of lime is less soluble in hot than in cold, fresh, or sea-water.

For temperatures above 100° cent. the solubility of the sulphate of lime in sea-water diminishes nearly in proportion to the increase of temperature; and, consequently, this solubility diminishes very rapidly with the corresponding increase of pressure.

The following table indicates this solubility for different temperatures, as well as the degrees of concentration at which the saturation of sulphate of lime has place:—

Degrees of the Areometer corresponding to the Saturation.	Temperatures.	Pressures in Atmospheres.	Solubility or Proportion of Sulphate of Lime in 100 of Water at Saturation.
	Degrees.	Atmos.	
12½	103·00	1	0·500
12	103·80		0·477
11	105·15		0·432
10	108·60	1¼	0·395
9	111·00		0·355
8	113·20		0·310
7	115·80	1½	0·267
6	118·50		0·226
5	121·20		0·183
4	124·00	2	0·140
3	127·60		0 097
2	130 00	2½	0 060
1	133 30		0·023

This table expresses that, for example, sea-water boiling at atmospheric pressure, or 103°, will arrive at saturation of sulphate of lime when it will have acquired the concentration of 12·5° of Baume, and then it will contain 0·500 per cent. of this salt; at 1·25 atmospheres, or 108·6° of temperature, the water will be saturated with sulphate of lime, when the areometer marks 10; it will then contain 0·395 per cent. of sulphate of lime; at two atmospheres, or 124° of temperature sea-water in its natural state, and before it has experienced any concentration, is very near the point where the saturation takes place—for the natural water-marks from 3 to 3·5°,—and in this case the saturation takes place at 4° of concentration.

2. Sulphate of lime becomes wholly insoluble either in sea-water or in soft water at temperatures comprised of 140 and 150° centigrade; and if we expose at these temperatures water containing some of this salt in solution, it is entirely precipitated in the form of little crystals, or of very thin pellicles, according as the salt is more or less abundant in the solution. The sulphate thus precipitated is redissolved after the cooling, but as much more slowly as the temperature at which it is deposited is elevated. That which is deposited at 150° takes many days to re-dissolve.

In the discussion which followed the reading of the paper,

Mr. Elder said he had a good deal to do with the working of boilers at from 30 lbs to 35 lbs pressure without surface condensers, and in some cases he had seen very extraordinary deposits. One naturally expected to find most deposit in the section of a boiler where there was most salt and lime; but in a boiler divided into eighteen parts he had found

to his surprise, that although in the last section there were two-and-a half times more salt in the water than in that of the first section, yet he could ascertain little difference in the quantity of deposit of lime in any section. He had therefore come to the same conclusion as the President, that the deposit depended upon the temperature of the water, and not upon the quantity of lime in it. The great difficulty they had to contend with in preventing deposit, was that of keeping the circulation in such a state as that the currents would prevent the deposit, for it was found that where there was a current in a boiler the lime did not deposit to any extent. There was certainly no evidence to show that the lime deposited more on account of the presence of a greater quantity of it. The Americans ran with a pressure of 40 lbs at sea, and they did not appear to suffer much from deposit. They seemed to overcome the deposit of lime by cleaning the boiler whenever they got into port. He was aware of boilers working at 30 lbs for six or seven years, and the deposit was not greater with that than at lower pressures. He was quite satisfied, with the President, that the lime deposited with pure sea-water, and with sea-water having twice or thrice the usual quantity of salt in it, was the same.

Mr. Lawrie remarked that apparently it was Mr. Napier's opinion that beyond a certain pressure the deposit of sulphate of lime was not aggravated by an increased pressure.

Mr. Elder observed that, though the lime separated from the water, yet it did not necessarily settle down unless it got into eddies. Where the heating surface was, it had no great tendency to deposit. It was found that the deposit occurred in places where there was no great current.

Mr. Lawrie said that they would naturally expect to find it down below the furnace. He asked whether it had been found in practice that there was a greater or less deposit in boilers working at 60 lbs pressure than at 30 lbs? He would infer from the discussion that the deposit of sulphate of lime was not greater at the higher pressure.

Mr. Elder had observed boilers working with salt-water for three or four months at 45 lbs pressure, and he could not say there was much difference between the deposit at that pressure and at 25 lbs. He believed, however, there was a greater tendency for the lime to separate from the water, but it did not necessarily settle down over the heating surface of the boiler.

Mr. Lawrie said that the gunboats, of which the late Mr. Hughes had great experience, worked at a pressure of 60 lbs, and no extreme difficulties have been experienced in them.

Professor Thomson suggested that the water might be filtered in a tube 10 or 12 feet long, in which it could be heated up to 150° cent., but this would probably take a good deal of power.

Mr. Elder remarked that nearly every engineer knew of examples of furnace crowns and furnace sides of steam boilers with salt-water tumbling in on account of the deposit of lime or salt on those parts; and it was always considered to be the result of too little blowing off,

any such accident being prevented by sufficient blowing off. Were there not other deposits formed at a greater degree of saturation? Suppose they had a quadruple strength of salt in the boiler, was the salt deposited of an injurious kind when it got to a certain density? When did the injurious deposit begin? He believed that when water got to those densities, the lime and the salt formed a crust, and became a non-conductor, and the surface got nearly red hot, and tumbled in. Now, if the lime came out at a temperature of 220°, one would suppose that it would do the same at 230° or 240°. He would have expected that the furnace of the "Lancefield" would have fallen in.

Mr. Jas. R. Napier answered that the sides of most furnaces bulged between the stays, but he did not know the cause of it.

Mr. Lawrie remarked that there seemed to be one very important fact ascertained—that the extensive use of refrigerators could not be attended with the good that was expected from them.

Mr. Jas. R. Napier explained the construction of the "Lancefield's" regenerator, and in reply to inquires, stated that it was about 11 feet high, 20 inches in diameter, and fitted with iron tubes of about ½-inch bore. The tubes gave way at the bottom near the feed inlet. It was very efficient while it lasted. Where there was less water discharged there would be less heat to be saved. Still, the regenerator would always be useful in saving a great portion of the heat that would otherwise be lost.

Mr. Elder observed that the regenerators in the "Shamrock" and "Thistle" wore away rapidly at the ends of the tubes, which were of brass, where the current of water impinged against them, which he believed arose from the mechanical friction caused by the velocity of the water. He would have expected that iron tubes would have gone much more quickly; for in the cases he had mentioned there was no appearance of galvanic action.

Mr. Lawrie said the old refrigerators did not wear away quickly, although the water struck against their brass ends.

Mr. Thomas Russell had seen regenerator tubes worn away both from mechanical action and other causes, such as by rust; whilst he also knew that they worked about ten years in the West India boats, and yet seemed pretty perfect after that, and certainly not worn out; so much so, that when they got new boilers, they repaired their regenerators, and continued to work them for years after that. He did not know whether they were still working them.

Manipulation of Metals.

From the London Mechanics' Magazine, October, 1861.

There are many occasions where a knowledge of some simple alloy or a peculiar solder would save hundreds, yes, thousands of dollars, just as a life may be saved by merely tying a pocket-hankerchief tight-

ly above a bleeding artery. It is only a few years ago that the valve-stem on the engine that runs the *Herald* presses broke in the dead of night, when but half the edition was run off. This was a dilemma, indeed, for a valve-stem is not made in half-an-hour, neither can it be bought at a hardware store like a pound of nails. The engine was injured in a vital part, and unless it was mended the entire edition would be stopped and incalculable loss sustained. Fortunately for the proprietors there was one of the employees present who understood the manipulation of metals, and he informed the by-standers that if they would collect their spare silver he would restore the broken part to a condition of usefulness.

It was done.

The stem was brazed with silver solder, and the engine performed until morning, so that the whole edition was successfully run off. But for the presence of the adept referred to, and his knowledge of this simple process, very great loss would have been incurred.

Some of our readers may be caught in just such a predicament, and we therefore append a formula for a solder which will braze steel. It is as follows: Silver 19 parts; copper 1 part; brass 2 parts; if practicable charcoal dust should be strewed over the melted metal in the crucible.

A good article of yellow brass is extremely desirable for fine work in telescopes and optical instruments generally. A metal that works free and soft under the tool, and is capable of receiving a fair lustre from the burnisher, is always in request. A good yellow brass can be made from the following metals: That denominated "watch-makers brass" is made of one part copper and two parts zinc. German brass is equal parts of copper and zinc; the addition of a little lead makes the metal work easier and less liable to tear under the tool.

In all these mixtures the zinc must be added last, as it is a volatile metal and fuses at a much lower heat than the copper; the melting point of which is 4587°, while that of zinc is only 700°.

Iron and brass must be united by spelter, which is equal parts of brass and zinc. When the joints are cleaned and wired together fine powdered borax is applied to them as a flux. The solder is then dusted on in the form of a powder, or fine filings, and melted in either with a blow-pipe, or by being placed in a charcoal fire. Care must be taken not to melt the brass to be brazed. The solder of course has a much lower fusion point than the metals to be joined, else they would both run at the same time.

A simple method of case-hardening small wrought iron work is to make a mixture of equal parts of pulverized prussiate of potash, saltpetre, and sal ammoniac. The articles must be heated to a dull red, then rolled in this powder, and afterwards plunged into a bath of four ounces of sal ammoniac and two ounces of potash dissolved in a gallon of water.

These simple rules are practical, and will give good results with good workmanship. If the wrought iron is overheated and burned, the unskilful workman must not blame the formula for his failure; or

if he put on such a blast as to blow the solder out of the joints, when brazing, and instead of making a joint spoils the job, he must not charge it upon us, but keep a brighter look-out in future. Good rules are useless unless put in force and practised with skill and intelligence.—*Scientific American.*

Storing Explosive Materials.

From the London Artizan, Dec. 1864.

A very interesting operation, which attracted a great number of spectators, has been performed recently at St. Ouen, near Paris. A large floating dock on a new construction—210 feet long, 36 feet wide, and 18 feet high—was launched on the canal. This great iron boat, or floating dock, is intended for a store to hold all description of spirits, oils, or other inflammable liquids. These substances which are so frequently the cause of disastrous fires on land, are now to be secured on water, where they will be comparatively safe from fire. Each of the 100 compartments into which the iron boat is divided is sufficient to contain 250 hectolitres. Ten similar floating warehouses are to be built for the company of the docks of St. Ouen, of which five are already on the stocks. The iron boat was launched sideways into the canal of St. Ouen. After having glided along the slides placed under it, the iron mass, once in the water, moved forward more than forty yards by the force of impulsion. The operation was performed with complete success.

Preservation of Iron in Water.

From the London Artizan, Dec., 1864.

At a sitting of the Academy of Sciences, M. Becquerel read a paper on the preservation of cast iron and iron in fresh water. He had previously shown that when a plate of either material was in contact with a zinc plate not exceeding the hundredth part of the surface of the former, the intensity of the derived electrical currents on the protected metal (iron) would, in sea water, diminish as the distance from the point of contact of the two metals increased; but nevertheless so that the protection afforded by these derived currents would still extend to a considerable distance from the said point of contact. In fresh water there are fewer divided currents on the surface of the metal, a fact which M. Becquerel attributes to the difference of conductability of the two liquids and the degree of chemical action which each exercises on the zinc, since these two circumstances both tend to increase the intensity of the currents. M. Becquerel concludes with saying that a pile of 9837 cannon-balls, 12 centimetres in diameter, may be protected from oxidation under water by surrounding it with zinc bands having an aggregate surface of two square metres.

On the Chemical History and Application of Gun Cotton. By Prof. Abel, F.R.S., Chemist to the War Department.

From the London Chemical News, No. 234.

The history of gun cotton affords an interesting illustration of the facility with which the full development of a discovery may be retarded, if not altogether arrested, for a time, by hasty attempts to apply it to practical purposes before its nature has been sufficiently studied and determined. When Schönbein, in the Autumn of 1846, announced that he had discovered a new explosive compound, which he believed would prove a substitute for gunpowder, the statement attracted general attention, and attempts were made with little delay in different countries to apply the material to purposes for which gunpowder hitherto had been alone used. Schönbein and Böttger (who appear to have discovered gun cotton independently shortly after the former had produced it) lost little time in submitting their discovery to the German Confederation; and a committee was appointed for its investigation, by whom gun cotton was eventually pronounced inapplicable as a substitute for gunpowder.

In this country, gun cotton was experimented with immediately after the method of its preparation was published by Schönbein. Researches were instituted into its nature, preparation, &c., by Porrett and Teschemacher, John Taylor, Gladstone, and others. A few experiments were made on its application as a propelling and mining agent, and the manufacture of the material upon a considerable scale was set on foot by Messrs. Hall, the well-known gunpowder makers at Faversham, a patent having been previously taken out in this country for the production of gun cotton according to Schönbein's process. This factory had, however, not been long in operation before a very disastrous explosion occurred at the works, by which a number of men lost their lives, and which was ascribed to the spontaneous ingnition of the gun cotton, by the jury who endeavored to investigate its cause. From that time the manufacture of gun cotton upon any considerable scale was abandoned in England, and no important contributions to our knowledge of this material were made until, in 1854, Hadow published the results of some valuable investigations, which served to furnish a far more definite knowledge regarding the true constitution and proper method of producing gun cotton than had hitherto existed.

In France, gun cotton was also made the subject of experiments as early as the winter of 1846, and its manufacture was carried on at the Government powder works at Bouchet, near Paris. Some interesting balistic experiments were instituted, under the direction of Piobert, Morin, and other men of eminence, with gun cotton in comparison with different kinds of gunpowder, the results of which indicated that, for producing equal effects to those furnished by a given weight of gun cotton, it was necessary to employ a double quantity of sporting powder, three times the quantity of musket powder, and four times the weight of cannon powder. It was also found that the best results appeared to be obtained by arranging the gun cotton so that it should

occupy the same space as the charge of gunpowder required to produce an equal effect; and other data were arrived at, which show that the investigators were being led to work in a direction similar to that afterwards so successfully pursued by Baron Von Lenk in Austria. Unfortunately, however, disastrous explosions occurred at the works at Bouchet, one as early as March, 1847, in a drying chamber, and two, following closely upon each other, in 1848. One of these took place in a magazine near which it was believed that nobody had been for several days; the other occurred also in a magazine where gun cotton was being packed, and on this occasion several lives were lost. These disasters appear to have put an end, until quite recently, to experiments with gun cotton in France.

After the material had been pronounced upon unfavorably by the Committee of the German Confederation, one of its members, Baron von Lenk, continued to devote himself to its study, and with such success, it appears, that a Committee was eventually appointed by the Austrian Government in 1852, to inquire fully into the merits of the material. A sum of money was paid to Schönbein and Böttger in recognition of the value of their discovery, and an experimental manufactory of gun cotton was established at the Castle of Hirtenberg, near Vienna. A particular form of cannon was devised by Baron von Lenk for employment with gun cotton, of which a 12-pounder battery was established. The performances of these guns were considered sufficiently satisfactory to warrant the preparation of four more batteries, which were sent to the Army of Observation in Galicia in 1855, but did not go into active service. It appears that, in consequence of a want of uniformity in the effects of the gun cotton, and of an injurious effect upon the guns, added probably to the prejudice entertained against it by the artillery, the material fell into disfavor, and its application in cannon was for a time abandoned. It was received, however, with much greater favor by the engineers, and was applied with great success to mining and submarine operations. Meanwhile, Baron von Lenk's labors to perfect gun cotton as a material for artillery purposes were unceasing; and at the close of the Italian war the subject of its application was again thoroughly re-opened at the instigation of Count Degenfeld, then Minister of War, who had at an earlier period taken an active interest in Baron von Lenk's investigations. After upwards of one year's experiments, a system of rifled field and mountain guns, to be employed with gun cotton which had been elaborated by von Lenk, was introduced into the Austrian service. Thirty batteries of these guns were equipped, and it was considered as definitely settled that gun cotton would before long be introduced into the service in the place of gunpowder, for artillery purposes. In 1862, however, an explosion occurred at Simmering, near Vienna, where both gunpowder and gun cotton were stored, and this disaster appears to have fortified to such an extent the arguments which were adduced against the employment of gun cotton by its opponents in the artillery service that its use in this direction was again put a stop to for a time. Ultimately a Committee of Investigation was appointed,

which consisted in part of eminent scientific men, and which appears, after careful deliberation, to have reported highly in favor of the stability, and important properties as an explosive, of the material,—a report which was supported by the favorable opinion entertained of gun cotton by the Austrian engineers, in whose name Baron von Ebner prepared a very complete and interesting account of the properties and effects of the agent, with particular reference to mining and other engineering operations.

Gun cotton appears, therefore, to have been again restored to favor in Austria, but no official account has reached England up to the present time, with regard to its employment in the recent war operations in that country.

In the Spring of 1862, full details relating to the manufacture and modes of applying gun cotton were communicated by the Austrian Government to that of Her Majesty, and the War Office chemist was at once instructed to institute experiments upon the manufacture of gun cotton, and upon its chemical constitution and stability. In the Autumn of that year General Sabine directed the attention of the British Association to the results obtained with gun cotton in Austria, and a combined Committee of engineers and chemists was appointed to inquire into the subject. At the meeting of the Association in 1863, this Committee presented a report, which was based upon information received partly from General von Lenk, who had been permitted by the Austrian Government to visit this country for the purpose of communicating fully with the British Association on the subject, and partly upon the results already arrived at in the experiments instituted by the lecturer under the direction of the Secretary of State for War. Subsequently a Committee of investigation was appointed by the latter, under the presidency of General Sabine, composed of scientific men connected with the Royal Society and British Association, and of military and naval officers of considerable experience; and this Committee has been entrusted with the full investigation of the properties of gun cotton, as improved by Baron von Lenk, with reference to its application to military, naval, engineering, and industrial purposes.

The chemical constitution of gun cotton, concerning which the opinions of chemists were divided until 1854, has been conclusively established by the researches of Hadow. In the formation of substitution-products by the action of nitric acid upon cotton or cellulose, three atoms of the latter appear to enter together into the chemical change, and the number of atoms of hydrogen re-placed by peroxide of nitrogen in the treble atom of cellulose—

$$C_{18}H_{30}O_{15}=3(C_6H_{10}O_5)$$

may be nine, eight, seven, or six, according to the degree of concentration of the nitric acid employed.

The highest of these substitution-products is tri-nitro cellulose, pyroxilin, or gun cotton,—

$$C_{18}\left\{\begin{matrix}H_{21}\\9NO_2\end{matrix}\right\}O_{15}=3C_6\left\{\begin{matrix}H_7\\3NO\end{matrix}\right.O_5;$$

this being the substance first produced by Pelouze in an impure condition, in 1838, by the action of very concentrated nitric acid upon paper, or fabrics of cotton, or linen, and afterwards obtained in a purer form by Schönbein, who employed a mixture of concentrated nitric and sulphuric acids for the treatment of cotton-wool; the object of the sulphuric acid being to abstract water of hydration from the nitric acid, and also to prevent the action of the nitric acid from being interfered with by the water which is produced, as the chemical transformation of the cotton into gun cotton proceeds. The formation of trimitro-cellulose is represented by the following equation:—

$$\underset{\text{Cotton.}}{C_6H_{10}O_5} + 3\underset{\text{Nitric acid.}}{\left\{\begin{matrix} H \\ NO_2 \end{matrix}\right\}}O = \underset{\text{Gun cotton.}}{C_6\left\{\begin{matrix} H_7 \\ 3NO_2 \end{matrix}\right\}O_5} + 3\underset{\text{Water.}}{\left\{\begin{matrix} H \\ H \end{matrix}\right\}}O.$$

The lowest substitution-product for cotton, of those named above, appears to have the same composition as the substance which Braconnet first obtained in 1832, by dissolving starch in cold concentrated nitric acid, and adding water to the solution, when a white, highly combustible substance is precipitated, to which the name of *Xyloïdin* was given. The substitution-products from cotton, intermediate between the lowest and highest, are soluble in mixtures of ether and alcohol, and furnish by their solution the important material *collodion*, so invaluable in connexion with photography, surgery, experimental electricity, &c.

According to Schönbein's original prescription, the cotton was to be saturated with a mixture of one part of nitric (of sp. gr. 1·5) and three parts of sulphuric acid (sp. gr. 1·85), and allowed to stand for one hour. In operating upon a small scale, the treatment of cotton with the acid for that period is quite sufficient to effect its complete conversion into the most explosive product *pyroxilin*, or *trinitrocellulose*; but when the quantity of cotton treated at one time is considerable, especially if it is not very loose and open, its complete conversion into pyroxilin is not effected with certainty unless it be allowed to remain in the acid for several hours. This accounts in great measure for the want of uniformity observed in the composition of gun cotton and its effects as an explosive, in the earlier experiments instituted; and it is moreover, very possible that the want of stability and, consequently, even some of the accidents which it was considered could only be ascribed to the spontaneous ignition of the material, might have been due to the comparatively unstable character of the lower products of substitution, some of which existed in the imperfectly-prepared gun-cotton.

The system of manufacture of gun cotton elaborated by General von Lenk is founded upon that described by Schönbein; the improvements which the former has adopted all contribute importantly to the production of a thoroughly uniform and pure gun cotton; there is only one step in his process which is certainly not essential, and about the possible utility of which chemical authorities are decidedly at variance with General von Lenk.

The following is an outline of the process of manufacture of gun

cotton as practised by Lenk. The cotton, in the form of loose yarn of different sizes, made up into hanks, is purified from certain foreign vegetable substances by treatment for a brief period with a weak solution of potashes, and subsequent washing. It is then suspended in a well ventilated hot air chamber until all moisture has been expelled, when it is transferred to air-tight boxes or jars, and at once removed to the dipping tank, or vessel where its saturation with the mixed acid is effected. The acids of the specific gravity prescribed by Schönbein are very intimately mixed in a suitable apparatus in the proportions originally indicated by that chemist, *i.e.*, three parts by weight of sulphuric acid to one of nitric acid. The mixture is always prepared some time before it is required, in order that it may become perfectly cool. The cotton is immersed in a bath of the mixed acids, one skein at a time, and stirred about for a few minutes, until it has become thoroughly saturated with the acids; it is then transferred to a shelf in this dipping trough, where it is allowed to drain and slightly pressed to remove any large excess of acid, and is afterwards placed in an earthenware jar provided with a tightly-fitting lid, which receives six or eight skeins, weighing from two to four ounces each. The cotton is tightly pressed down in the jar, and if there be not sufficient acid present just to cover the mass, a little more is added: the proportion of acid to be left in contact with the cotton being about ten and a-half pounds to one pound of the latter. The charged jars are set aside for forty-eight hours in a cool place, where, moreover, they are kept surrounded by water to prevent the occurrence of any elevation of temperature and consequent destructive action of the acids upon the gun cotton. The same precaution is also taken with the dipping trough, as considerable heat is generated during the first saturation of the cotton with the acids. At the expiration of forty-eight hours the gun cotton is transferred from the jars to a centrifugal machine, by the aid of which the excess of acid is removed as perfectly as is possible by mechanical means, the gun cotton being afterwards only slightly moist to the touch. The skeins are then immersed singly into water, and moved about briskly, so as to become completely saturated with it as quickly as possible. This result is best accomplished by plunging the skeins under a fall of water, so that they become at once thoroughly drenched. If they are simply thrown into the water and allowed to remain at rest, the heat produced by the union of a portion of the free acids, with a little water would be so great as to establish at once a destructive action upon the gun cotton by the acid present. The washing of the separate skeins is continued until no acidity can be detected in them by the taste; they are then arranged in frames or crates and immersed in a rapid stream of water, where they remain undisturbed for two or three weeks. They are afterwards washed by hand to free them from mechanical impurities derived from the stream, and are immersed for a short time in a dilute boiling solution of potashes. After this treatment, they are returned to the stream, where they again remain for several days. Upon their removal they are once more washed by hand, with soap if necessary; the pure gun cotton

then only requires drying by sufficient exposure to air at a temperature of about 27° C. to render it ready for use. A supplimentary process is, however, adopted by General von Lenk, about the possible advantage or use of which his opinion is not shared by others, as already stated. This treatment consists in immersing the air-dried gun cotton in a moderately strong, hot solution of soluble glass (silicate of potassa or soda) for a sufficient period to allow it to become completely impregnated, removing the excess of liquid by means of the centrifugal machine; thoroughly drying the gun cotton thus "silicated" and finally washing it once more for some time until all alkali is abstracted. Lenk considers that by this treatment some silica becomes deposited within the fibers of the gun cotton, which, on the one hand, assists in moderating the rapidity with which the material burns; and on the other hand, exercises (in some not very evident manner) a preservative effect upon the gun cotton, rendering it less prone to undergo even slight changes by keeping. The mineral matter contained in pure gun cotton which has not been submitted to this particular treatment amounts to about one per cent. The proportions found in specimens which have been "silicated" in Austria and in this country, according to Lenk's directions, varies between 1·5 and 2 per cent. It is difficult to understand how the addition of 1 per cent. to the mineral matter, in the form chiefly of silicate of lime and magnesia (the bases being derived from the water used in the final washing) which are deposited upon and between the fibers in a pulverulent form, can influence to any material extent either the rate of combustion or the keeping qualities of the product obtained by Lenk's system of manufacture.

Gun cotton prepared according to the system just described, is exceedingly uniform in composition. The analyses prepared both at Austria and at Waltham Abbey have furnished results corresponding accurately to those required by the formula—

$$C_6 \left\{ \begin{matrix} H \\ 3\,N\,O_2 \end{matrix} \right\} O_5.$$

In its ordinary air-dry condition, it contains, very uniformly, about 2 per cent. of moisture—an amount which it absorbs rapidly from the air when it has been dried. The proportion of water existing in the purified air-dried cotton, before conversion, is generally about 6 per cent. When pure gun cotton is exposed to a very moist atmosphere or kept in a damp locality, it will absorb as much as from 6 to 7 per cent.; but if it be then exposed to air of average dryness, it very speedily parts with all but the 2 per cent. of moisture which it contains in its normal condition. It may be preserved in a damp or wet state apparently for an indefinite period without injury; for if afterwards dried by exposure to air, it exhibits no signs of change.

In these respects it possesses important advantages over gunpowder. The normal proportion of hygroscopic moisture in that substance varies three-quarters and one per cent.; but if exposed in any way to the influence of a moist atmosphere, it continues to absorb water until,

however firm the grain may have originally been, it becomes quite pasty. It need scarcely be stated that when once gunpowder has become damp it can no longer be restored to a serviceable condition, except by being again submitted to the processes of manufacture, starting almost from the commencement.

Perhaps the most vital considerations bearing upon the possibility of applying gun cotton to important practical purposes, are those which relate to the risk likely to be incurred in its manufacture and preservation, in large quantities. The manufacture of gun cotton is, unquestionably, much safer than that of gunpowder; in fact, there is no possibility of accident until the final drying process is reached, as in all other stages, the material is always wet, and therefore harmless. With the adoption of a proper system of warming and ventilation in the drying chamber, the last operation is certainly not a more dangerous one than that of gunpowder. The question of the safe preservation of gun cotton cannot, as yet, be so easily and satisfactorily disposed of. Specimens of gun cotton exist which were prepared according to Schönbein's directions in 1846, and which have undergone no change whatever; on the other hand, it is well known that gun cotton which was believed to have been perfectly purified, has become extremely acid, and has even undergone so complete a decomposition as to have become converted into oxalic acid and other organic products, when preserved in closed vessels, and especially when exposed continuously or occasionally to light. This susceptibility to chemical change has become particularly observed in samples of gun cotton known to consist chiefly, or to contain some proportion, of the less explosive or lower substitution products (*i. e.*, gun cotton specially prepared for the manufacture of collodion). Hence it is very possible that such instances as are considered to have been well authenticated, of the spontaneous ignition of gun cotton when stored in considerable quantities, or during exposure to very moderate heat, may have arisen, not simply from an imperfect purification of the material, but also from the more or less imperfect conversion of cotton into the most explosive and apparently most stable product.

There is no doubt that the improvements effected in the system of manufacture of gun cotton have been instrumental in rendering it far more stable in character than it was in the early days of its production upon a considerable scale. At the same time, although Gen. von Lenk and its warmest partisans consider that its unchangeability can no longer be disputed, a greater amount of experience, combined with more searching investigation than have hitherto been instituted, upon the possibility of its undergoing change when under the influence of moderate heat, alone or combined with that of moisture, or when preserved under a variety of conditions, are unquestionably indispensable before its claims to perfect permanence can be considered as properly established. It has already been ascertained, by very recent experiments of the lecturer, that gun cotton prepared and purified with the most scrupulous care speedily undergoes some amount of decomposition when exposed to temperatures ranging from 32° to 66° C.;

it remains to be seen whether such decomposition, if once established by exposure of gun cotton to some temperature within the above limit, will cease permanently when the material is removed from the influence of heat, or whether precautions or efficient supplementary processes can be adopted in the manufacture, to counteract the tendency to change exhibited by gun cotton under the above circumstances. These are only some of the points which need patient investigation before it is positively known whether the requisite confidence can be placed in the material, as an agent susceptible of substitution for gunpowder.

It has been ingeniously argued that a slight indication of spontaneous change in gun cotton need give rise to no alarm, because gunpowder is also liable to slight spontaneous change, reference being made to the fact that a very minute proportion of the sulphur in that material has been noticed to undergo oxidation. It need hardly be stated that such a minute change cannot have the slightest effect upon the stability of the mechanical mixture, gunpowder, in which variations as regards purity and proportions of ingredients occur to an extent which render this change of absolute insignificance; whereas, in the case of gun cotton as now manufactured, the development of acid, however minute the proportion, may very possibly give rise to an important disturbance of chemical equilbrium in a compound, the stability of which is based upon the perfect uniformity of its composition; and it may also be at once productive of further change by the tendency which the acid itself has to exert in chemical action upon certain elements of the gun cotton.

The general properties of gun cotton as an explosive agent have long been popularly known to be as follows:—When inflamed or raised to a temperature ranging between 137° and 150° C. it burns with a bright flash and large body of flame, unaccompanied by smoke, and leaves no appreaciable residue. It is far more readily influenced by powerful percussion than gunpowder; the compression of any particular portion of a mass of loose gun-cotton between rigid surfaces will prevent that part from burning when heat is applied. The products of combustion of gun cotton in air redden litmus paper powerfully; they contain a considerable proportion of nitric oxide, and act rapidly and corrosively upon iron and gun-metal. The explosion of gun cotton when in the loose, carded condition—the form in which it was always prepared in the early days of its discovery—resembles that of the fulminates in its violence and instantaneous character. In the open air it may be inflamed when in actual contact with gunpowder without igniting the latter; in a confined space, as in a shell or in the barrel of a gun, the almost instantaneous rapidity of its explosion produces effects which are highly destructive as compared with those of gunpowder while the projectile force exerted by it is comparatively small.

Supply of Water to Cities.

From the Lond. Practical Mechanic's Journal, December, 1864.

M. Grimand de Caux, the French hydraulic engineer, has just read (8th Aug., 1864) a very interesting notice to the Academy of Sciences at Paris, entitled—"Theoretic and Practical indications relative to the employment, by the Canal of Marseilles, of the waters of the Durance, for domestic use, or for manufactures."

It is well known that Marseilles is supplied with water by the river Durance, which, conducted in artificial channels over limestone mountains and across several valleys—one passed by the celebrated Roque-Faveur aqueduct—for a total distance of about 40 miles, is at last delivered into the numerous fountains of the city; sweeps past every curb-stone in its streets, flushes out its sewers, and at last delivers a copious volume into the old *Toliette*, or inner harbor, and sweeps out to sea the formerly festering mass of putrescent matter that had collected and silted up much of its depth, and often in past times spread pestilence within the city, to which its waters brought trade and wealth. In this latter respect the supply from the Durance has been a matter of unmixed good to Marseilles. The *quality* of the water, however, the quantity of which is so abundant, appears to be by no means so satisfactory; in fact, it appears to be almost unwholesome, and in a very peculiar way unsuited both for manufacturing and for horticultural or agricultural purposes.

The water of the Durance, collected over a vast surface of sub-alpine limestones, is at all times surcharged with an argillaceous mud of excessive fineness. This mud, after its deposit, has been analyzed by M. Pisani. It consists, in 100 parts, of—

Aluminous clay, . . .	56·0
Carbonate of lime, . . .	39·6
Water not expelled at atmospheric temperature, .	4·4
	100

After the most prolonged repose, the whole of this sediment is not deposited, and the water still remains permanently opalescent. Mud deposits sensibly for five days of perfect repose, and after that the opalescence remains unchanged for lengthened periods, if not permanently.

When this water, as delivered by the aqueducts, is employed for watering crops, it has been proved to become a gradual but complete destroyer of fertility. The plants are, in fact, *stifled;* the *stomata* of their root-fibres become plugged up with this impalpable sediment, drawn in along with the water from the soil.

The Durance, in its own natural channel, after it has run as far as Avignon, Orgon, Pertuis, and other towns upon the lower river, is probably not in this state. In virtue of that wonderful power of separation that mere surface contact possesses, the water, while the river is in regimen, is cleared by passing for many miles over its gravely bed.

But amongst the hills, in the neighborhood of St. Paul, where the water has been diverted in order to preserve the necessary head, the

slightest rains produce muddiness, and the Marseilles Canal receives the water at once in this state.

When this canal was first projected, there would be in the suburbs of Marseilles about 6000 hectares of land to water. As, according to M. Boussingault, each square metre of land requires in summer (in that locality) from 3 to 4 litres of water per day, there is required for that purpose alone, for the 6000 hectares, or 60,000,000 of square metres, a minimum of 180,000 cubic metres of water. By the aid of settling basins, it is possible to avoid, in part at least, the evil effects of all this mud on vegetation. The upper portion only of the whole depth of water might be drawn off for delivery on the land.

Such a process is applicable to moderate surfaces of cultivated land at least, as, for example, of the gardens around Marseilles, for which, without extravagant cost, settling basins might be provided; but can it be extended to clarify 900,000 cubic metres.

In fact, the municipality of Marseilles has already constructed four great settling basins on the line of the canal; but notwithstanding the repose of the waters in these basins, it enters the pipes of Marseilles still loaded with as much as 33 grammes (or nearly 2000 grains) of mud in the cubic metre. At the present moment (with praiseworthy energy) the city is constructing a fifth settling basin at Réaltort, to contain 3,750,000 cubic metres, and with a water surface of 75 hectares. It is obvious that while basins of this magnitude are exposed to the wind, that sufficient agitation will be propagated from the surface, almost at all times, to prevent a complete deposit of sediment so excessively communicated as this mud of the Durance. In the end, should pellucid water not be thus procured, resort must be had to filtration through sand beds, like those of the double filtering basins of Chelsea. Such filtering beds, which would have to be constructed on the banks of the river, at the point of diversion of the canal, must, on a great scale, be divided into several separate areas for clearing out, &c., and provide for the deposit of about 4 kilogrammes of mud for each cubic metre of content.

However, M. Grimand de Caux continues, the fertilization of the soil is in this case a secondary object. The primary one is to fully and properly supply the city, so that all, rich and poor, shall be provided with good drinking water; until that is accomplished, he rightly says, that in sight of the vast work it has constructed, Marseilles is *not supplied*.

The civic needs are twofold—water for domestic use, and water for manufacturing purposes. M. de Caux calculates that the actual want of Marseilles is, on the whole, 500 cubic metres for 250,000 inhabitants per diem.

Occasional or unusual domestic demands, he thinks, may merge into those for manufacturing uses, and that both may be amply met by a supply of 25,000 cubic metres per diem.

The water capable of being brought in by the aqueduct is greatly beyond these demands. 25,500 cubic metres of the whole should then be deprived of its suspended matter, and the residue of the total delivery

after having, at the public fountains, spouted and been divided into *liquid powder* in the air, for the purpose of refreshing it, and promoting the health of the inhabitants, and then circulating past the water kennels, to sweep away their putridity, is to be delivered into the harbor.

With the head of pressure at command in the pipes of distribution the problem of filtration for domestic use appears to M. de Caux to be readily solved. The water will rise far above the top stories of any of the buildings.

He proposes to effect the filtration at the level of the street *in transitu* from the mains to the service pipes.

He fixes the following as primary conditions of filtration:—

The filtering material should be neutral, inert, and incapable of acting injuriously on the water, and acting mechanically only in the removal of the suspended matter. Such are the siliceous gravels and sands of various fineness as set forth by Arago in his report (on Filtration of Paris Water) of 1837. Any substance of organic origin, vegetable or animal, such as sponge, wool, &c., &c., should be excluded as liable to be destroyed by maceration, getting decomposed, and fouling the water passing through them, by microscopic particles of their detritus, or charging it with gases developed in putrefaction.

It is not sufficient for drinking water that it shall have ceased to deposit any sediment, it should be as transparent as crystal, and more especially for the case of a climate such as Marseilles, it should also be fresh and cool.

The water from the main pipes of Marseilles is in each house, whether occupied by one family or in "*apartments*," taken up by a service pipe to the top of the building, and there delivered into a single cistern, and is checked by a self-acting valve or cock; from this cistern distributing pipes proceed downwards to each floor, or each set of rooms. The general arrangements being like those adopted for that part of Paris supplied by the fountain of Gaillon, and also of Genoa, where, however, the water, it is said, is delivered by meter.

For all other domestic uses, except drinking, the water is used in its opaline state. For the purpose of rendering it at once pellucid and cool a form of portable domestic filter has been devised by Capt. Aman Vigié, an inhabitant of Marseilles, which is said to act perfectly in the double capacity required of it—namely, that of filtration and refrigeration. It is of the simplest character, though well calculated for its proposed object. Two vessels of pottery, each holding a few gallons, are prepared so that one can be steadily superimposed on the other, without cement or fixture. Into the upper one, which has certain perforations in the bottom, coarse siliceous gravel first, and then two finer qualities of sea sand, all carefully washed, (and sold in that state to the inhabitants,) are filled in and pressed gently down. When the vessel is nearly full, a flat circular plate of pottery, pierced full of small holes, is laid upon the top surface of the sand. This top vessel is glazed inside and out. The lower vessel is made of extremely porous earthenware, like that of the Spanish *alcarazzas*, and has one aperture at one side near the bottom, with an external neck to which a length of vul-

canized india rubber tube can be adapted. The length of this tube is a foot or so more than the total height of the two vessels when superimposed. In this state the little apparatus is placed upon a convenient stand, beneath a tap or cock leading from the house cistern, and by preference a position for it in a sharp draught of air is preferred. The cock is turned to the extent that experience shows will supply water as fast as it will filter through. The actual mode of working is to turn on the water by hand when the lower vessel or magazine needs replenishment, and so to turn it off when filled; but it is obvious that the supply might be made automatic easily, and equal to the demand at any moment.

The pellucid water passes into the lower vessel, and therein it becomes cooled, the rapid evaporation from its porous sides producing a powerful refrigeration. The india rubber tube from the adjutage of the lower vessel is brought vertically up the side of the apparatus, and the loose end left lying across the top—in that position, obviously, no water can escape by it. Whenever it is needed to draw off the water, the loose end of the pipe is lowered to the requisite level, and the water flows out into any other vessel held beneath its open extremity.

Thus, without a single close joint or metallic fitment, or valve, or cock, the whole apparatus is complete. It is cheap and simple to the last degree. The aëration of the water is said to proceed in the lower vessel, in virtue of its porous sides, with great vigor, so that drinking water, fully charged with air, and at or below 40° Fah., in the hottest weather, is always commanded.

When the sand, after some weeks use, has begun to get clogged, it is taken out and thrown away, and a fresh charge put in.

Domestic filtering apparatus is common enough in all parts of Europe, but everywhere that we are aware of is constructed on much more expensive and complex designs than this which we have described.

In some, sponge is the filtering medium, the objections to which were long ago pointed out by Arago; in others, porous stones, such as Ransomes; or porous plates, made up of charcoal or coke and baked earth; or woven tissues, &c., form the filtering media. To all these there are objections, in first cost and in use. None of these domestic filters that ever we have seen, combine the advantage of the *alcarazza* principle of cooling in the recipient vessel. This appears to us to be the greatest merit of M. Vigié's filter.

We make no doubt but that this domestic apparatus may practically be found to work well in the actual *regime* of life at Marseilles, and, after a time, if indispensable, would, no doubt, be found to do so in England or elsewhere. The filter would come to be understood and worked as easily as moderator lamps, or gas lights, or water closets, and a thousand other more complex things are found to work. But we cannot, nevertheless, but regard the necessity for their adoption at Marseilles as a grave blot upon the hydraulic engineering that has procured for it its supply of water, worthy of all praise as it is in point of copiousness. It points to the fact so well insisted on by M. Gri-

mand de Caux, that too much care cannot be bestowed upon the preliminary inquiries that should be always instituted with the utmost rigidity of science, as to the physical and chemical qualities of the sources proposed to be made available by the hydraulic engineer.

Here is a case in which the beneficent results of one of the most magnificent water projects of modern days—if not of the world—are to a serious extent neutralized by the presence of an insignificant quantity of suspended matter.

The mud, chemically considered, is probably by no means deleterious as regards the calcareous constituent—certainly not so either to animals or plants; yet, in the impalpable division in which it is borne along with this Durance water, it is odious to the eye, if not disagreeable to the palate, and fatal to vegetation.

Without impugning the analysis of M. Pisani, we must entertain a doubt that he looked for silica in the water; and we apprehend that part of the clay or aluminous matter may probably consist in reality of minutely divided silex. If so, the confluent opinion of the physicians of all alpine countries, who have had long experience of the effects of the water of mountain torrents, bearing silica in this impalpable condition, is that it exercises peculiar and highly unwholesome effects upon the animal economy.

It is easy to see to innumerable ways in which opalescent, or slightly muddy water, used for every domestic purpose, with the *exception* of drinking, must yet be productive of disorder, inconvenience, and loss.

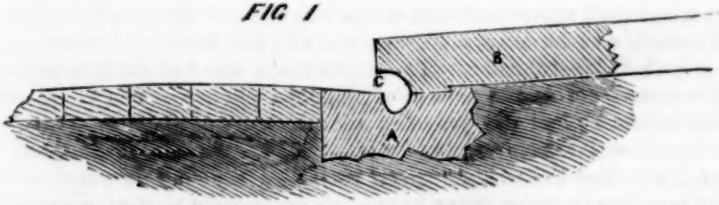
If anything *can* counterbalance such an evil, in the almost tropical climate (for a large part of the year) of Marseilles, it is the magnificent abundance of the supply.

This plentitude of water, delivered at a commanding altitude, is such that both sides of every street in the city runs a rivulet of water, by which the kennels are constantly swept of every impurity.

The water-tables at the curb-edges of very many of the flagged footways, are constructed on a peculiar and excellent plan of great simplicity, which might with advantage be adopted in many places in London and our other great towns.

Fig. 1, is a transverse section of one of those water-tables, the section being, of course, also transverse to the line of street.

FIG 1



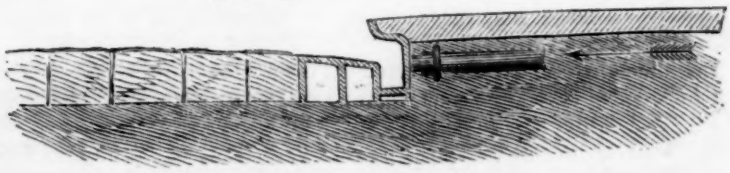
The line of stone blocks, A, form a solid abutment and curb for the pavement, or Macadamising, as the case may be. They are solidly bedded and jointed with asphalt. The hollow grooved channel, which is about 10 to 15 inches in each dimension, is wrought out of the stone, and a rabbet is prepared on the inside part of the top bed, to receive

the covering stone, B, which so overbands the former that a wheel or foot, when close to the edge of the footway or kerb, cannot slip into the trough. Every thing finds its way, in heavy rain, into the trough, and from its section, solid matters, such as are found on street surfaces, are swept along, usually without any stoppage, and into the main sewers. When a stoppage does occur, or during the continuance of nearly dry weather, the channels are cleared by sweeping along them a crooked iron instrument, introduced through the continuous slot, C.

The stone employed is Apennine, or sub-apennine limestone, in heavy blocks. The whole construction seems to stand well, and is exposed in several places to very heavy traffic. This construction presents the advantage of leaving the entire breadth of the roadway, from kerb to kerb, at once free for traffic, and free of puddles of nearly stagnant water. It protects the foot passenger from the direful splashing over with mud from the sudden rushing of wheels through the shallow kennell in wet weather, which is so commonly one of the sufferings of the London pedestrian, and, by substituting a form of channel which gives a minimum perimeter and maximum depth, it enables offal to be swept along by the current, that is imperfectly, or not at all, carried along our water kennels.

A form of the same sort of covered water kennel was designed, and, to a small extent, employed by the writer, some years since, constructed in cast iron, as seen in transverse section in fig. 2, and for London

FIG 2



streets would be more advantageous than the Marseilles pattern in stone, which involves a rather *higher* kerb than would suit many streets, in the City of London especially. The cast iron channel was cast in one piece, with the exterior curbing, against which the paving of the roadway abutted, and this was formed of hollow cancelated blocks, with roughened upper surfaces, much like those of Messrs. Ransomes, of Ipswich, as laid down some time since in the Poultry, London, and King Street, Westminster. The whole block was bedded in concrete, to the same level as the bottom of the road paving. The inner side of the hollow kennel was provided with faucetts at short intervals, to receive the water from rain-water trunks, or other lateral supplies.

At Marseilles the writer himself remarked that in fine weather the water running in these water kennels is frequently perfectly pellucid at the lower parts of the city, and affords another instance not unworthy of notice of how completely opalescent water is deprived of its suspended matter by long-continued agitation in flow, with large surface contact, and aeration at the same time.—*Ed.*

Substitutes for Indian Ink.

From the London Chemical News, No. 253.

A substance much of the same nature and applicable to the same purposes as Indian ink may be formed in the following manner:—Take of isinglass three ounces: make it into a size by dissolving over the fire in six ounces of soft water. Take then Spanish liquorice one ounce, dissolve it in two ounces of soft water over the fire in another vessel, then grind up on a slab, with a heavy muller one ounce of ivory black with the Spanish liquorice mixture. Then add the same to the isinglass size while hot, and stir well together till thoroughly incorporated. Evaporate away the water, and then cast the remaining composition into a leaden mould slightly oiled, or make it up in any other convenient way. This composition will be found quite as good as the genuine article. The isinglass size mixed with the colors work well with the brush. The liquorice renders it easily dissolvable, on the rubbing up, with water, to which the isinglass alone would be somewhat reluctant; it also prevents it cracking and peeling off from the ground on which it is laid. A good Indian ink may be made from the fine soot from the flame of a lamp or candle received and collected by holding a plate over it. Mix this with the size of parchment, and it will be found to give a good deep color. Burnt rice has been by some considered a principal ingredient in the genuine Indian ink, with the addition of perfumes or other substances not essential to its qualities as an ink.—*British Journal of Photography.*

Coppering Iron Ships.

From the London Artizan, Dec., 1864.

A mode of coppering iron ships, so as to secure freedom from galvanic action, and at the same time attach the sheating firmly, has been invented by Capt. Warren, and is at present in use at the works of Messrs. Brown & Simpson, iron ship-builders, of Dundee. The bottom of the ship to be coppered must be first thoroughly cleaned, and when dry coated all over with Hay's varnish, which must be applied whilst hot. The bottom of the iron ship is then covered with the insultating material used by Capt. Warren, which is a kind of felt of about a fourth of an inch in thickness, and the edges of the layers of this material are lapped over each other for a couple of inches, to insure perfect insulation of the iron. The felt is put on by means of marine glue on it and on the ship's bottom, and pressed hard home—the process presenting little mechanical difficulty. After the ship's bottom has been covered, the outside of the felt or insulator is coated with marine glue upon the parts which are to receive the copper. The copper, which must be previously coated with varnish, is then placed upon the glued felt, the edges of each sheet and layer overlapping the others, the same as in the case of wooden ships. Along these edges nail-holes have been driven for small nails to rivet them together—for though the copper sticks quite strongly enough to the felt, the edges which overlay each other are the better for being thus riveted. The nails for this purpose are very ingeniously contrived, the points of

each being split and slightly turned out, so that when they have passed through the two sheets of copper they came in contact with the insulator, and are opened out—thus forming, as Captain Warren says, a perfect clench. The effect of the water wash at the part of the side where the copper leaves off, has also been provided against by Capt. Warren, who carries right round the vessel a batten or beam, on which the upper edge of the copper is fastened, but which is beveled in towards the ship's side at its downward edge, so as to twist the copper violently.

Extracting the juice from Grapes.

From the London Mechanics' Magazine, October, 1864.

We learn from the *Chemical News* that a M. Richter, of Stuttgard, has devised a novel means of extracting the juice from grapes. Instead of pressing them in the ordinary way, he puts them in a drum provided with a suitable strainer, and rotating at the rate of 1000 or 1500 times a minute. The process is said to have the following advantages over the ordinary method:—The time required for the operation is greatly lessened, the whole of the must from one cwt. of grapes being obtained in five minutes; the quantity of juice is increased by five or six per cent.; "stalking" is rendered unnecessary; and the agitated must is so mixed with air that fermentation begins comparatively soon.

Preparation of Blue Ink with Prussian Blue. By M. A. Vogel.

From the London Chemical News, No. 255.

Prussian blue dissolves in oxalic acid, giving a dark blue limpid liquid. This interesting discovery of MM. Stephen and Rasch, patented in England in 1837, is of great interest in tinctorial chemistry, as by its means Prussian blue may be very simply used in the form of a solution. To dissolve commercial Prussian blue in oxalic acid, first mix the blue with concentrated hydrochloric or sulphuric acid, then add an equal weight of water, leave to digest for 48 hours, then carefully extract all the acid by repeated washings. This process being minute and tedious, it is better to employ recently precipitated Prussian blue, which does not need the previous treatment by a concentrated acid.

By the following process the author has always obtained a good solid blue ink with Prussian blue and oxalic acid:—

Dissolve in a matrass, in a large quantity of water, ten grammes of sulphate of protoxide of iron; boil, and then add sufficient nitric acid to sesquioxidize all the iron. Then add a solution of yellow prussiate of potash containing ten grammes of this salt and leave the precipitate to deposit. After decanting the supernatant liquid, throw the deposit on a filter, wash with cold water, and leave it to drain until it can be easily raised from the filter with a knife; then, without further drying, mix it in a porcelian mortar with two grammes of oxalic acid in crystals. Let the reaction continue for an hour, then gradually add 400 cubic centimetres of water. A dark blue solution is thus obtained, in which even after long standing no precipitate is to be found.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, December 15th, 1864.

William Sellers, President, in the chair.

John H. Cooper, Recording Secretary, pro tem.

The minutes of the last meeting were read and approved.

The Board of Managers and Standing Committees reported their minutes.

The Special Committees on Weights, Measures, and Coinage of the United States, and on Steam Expansion, reported progress.

The Special Committee on a Uniform System of Screw Threads, &c., presented the following report.

That in the course of their investigations they have become more deeply impressed with the necessity of some acknowledged standard, the varieties of threads in use being much greater than they had supposed possible; in fact the difficulty of obtaining the exact pitch of a thread not a multiple or sub-multiple of the inch measure is sometimes a matter of extreme embarrassment.

Such a state of things must evidently be prejudicial to the best interests of the whole country, a great and unnecessary waste is its certain consequence, for, not only must the various parts of new machinery be adjusted to each other in place of being interchangeable, but no adequate provision can be made for repairs, and a costly variety of screwing apparatus becomes a necessity. It may reasonably be hoped that should a uniformity of practice result from the efforts and investigations now undertaken, the advantages flowing from it will be so manifest as to induce reform in other particulars of scarcely less importance.

Your Committee have held numerous meetings for the purpose of considering the various conditions required in any system which they could recommend for adoption. Strength, durability, with reference to wear from constant use and ease of construction, would seem to be the principal requisites in any general system, for, although in many cases as, for instance, when a square thread is used, the strength of the thread and bolt are both sacrificed for the sake of securing some other advantage, yet all such have been considered as special cases, not affecting the general inquiry. With this in view, your Committee decided that threads having their sides at an angle to each other must necessarily more nearly fulfil the first condition than any other form; but what this angle should be must be governed by a variety of considerations, for it is clear that if the two sides start from the same point at the top, the greater the angle contained between them, the greater will be the strength of the bolt; on the other hand, the greater this angle, supposing the apex of the thread to be over the centre of its base, the greater will be the tendency to burst the nut, and the greater the friction between the nut and the bolt, so that if carried to excess the bolt would be broken by torsional strain rather than by a strain in the direction of its length. If, however, we should make one

side of the thread perpendicular to the axis of the bolt, and the other at an angle to the first, we should obtain the greatest amount of strength, together with the least frictional resistance; but we should have a thread only suitable for supporting strains in one direction, and constant care would be requisite to cut the thread in the nut in the proper direction to correspond with the bolt; we have consequently classed this form as exceptional, and decided that the two sides should be at an angle to each other and form equal angles with the base.

The general form of the thread having been determined upon the above considerations, the angle which the sides should bear to each other has been fixed at 60°, not only because this seems to fulfil the conditions of least frictional resistance combined with the greatest strength, but because it is an angle more readily obtained than any other, and it is also in more general use. As this form is in common use almost to the exclusion of any other, your Committee have carefully weighed its advantages and disadvantages before deciding to recommend any modification of it. It cannot be doubted that the sharp thread offers us the simplest form, and, that its general adoption would require no special tools for its construction, but its liability to accident, always great, becomes a serious matter upon large bolts, whilst the small amount of strength at the sharp top is a strong inducement to sacrifice some of it for the sake of better protection to the remainder; when this conclusion is reached, it is at once evident a corresponding space may be filled up in the bottom of the thread, and thus give an increased strength to the bolt, which may compensate for the reduction in strength and wearing surface upon the thread. It is also clear that such a modification, by avoiding the fine points and angles in the tools of construction, will increase their durability; all of which being admitted, the question comes up what form shall be given to the top and bottom of the thread? for it is evident one should be the converse of the other. It being admitted that the sharp thread can be made interchangeable more readily than any other, it is clear that this advantage would not be impaired if we should stop cutting out the space before we had made the thread full or sharp, but to give the same shape at the bottom of the thread would require that a similar quantity should be taken off the point of the cutting tool, thus necessitating the use of some instrument capable of measuring the required amount, but when this is done the thread having a flat top and bottom can be quite as readily formed as if it was sharp. A very slight examination sufficed to satisfy us that in point of construction, the rounded top and bottom presents much greater difficulties, in fact all taps and screws that are chased or cut in a lathe required to be finished or rounded by a second process. As the radius of the curve to form this must vary for every thread, it will be impossible to make one gauge to answer for all sizes and very difficult, in fact impossible, without special tools to shape it correctly for one.

Your Committee are of opinion that the introduction of a uniform system would be greatly facilitated by the adoption of such a form of thread as would enable any intelligent mechanic to construct it

without any special tools, or if any are necessary, that they shall be as few and as simple as possible, so that although the round top and bottom presents some advantages when it is perfectly made, as increased strength to the thread and the best form to the cutting tools, yet we have considered that these are more than compensated by ease of construction, the certainty of fit and increased wearing surface offered by the flat top and bottom, and therefore, recommend its adoption. The amount of flat to be taken off should be as small as possible, and only sufficient to protect the thread; for this purpose one-eighth of the pitch would seem to be ample, and this will leave three-fourths of the pitch for bearing surface. The considerations governing the pitch are so various that their discussion has consumed much time.

As in every instance the threads now in use are stronger than their bolts, it became a question whether a finer scale would not be an advantage, it is possible that if the use of the screw thread was confined to wrought iron or brass, such a conclusion might have been reached, but as cast iron enters so largely into all engineering work, it was believed finer threads than those in general use might not be found an improvement, particularly when it was considered that so far as the vertical height of thread and strength of bolt are concerned, the adoption of a flat top and bottom thread was equivalent, to decreasing the pitch of a sharp thread 25 per cent., or what is the same thing, increasing the number of threads per inch 33 per cent. If finer threads were adopted they would require also greater exactitude than at present exists in the machinery of construction, to avoid the liability of overriding, and the wearing surface would be diminished; moreover, we are of opinion that the average practice of the mechanical world would probably be found better adapted to the general want than any proportions founded upon theory alone.

We have taken some pains to ascertain what the proportions in use are, and submit the following, as being in our judgment a fair average, viz:—

Diameter of Bolt,	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$
No. of th'd per in.	20	18	16	14	13	12	11	10	9	8	7	7	6	6	$5\frac{1}{2}$	5	5
Diameter of Bolt,	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
No. of th'd per in.	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{1}{4}$

The proportions for bolt-heads and nuts, as given in most of our books of reference, are believed to be larger than necessary, and all are tabulated, necessitating constant reference, a simple formula would be more convenient, and would probably induce a uniform practice, but as most of the sizes in common use are made by machinery and also by hand, it is believed the bolt-head and nut for finished work should be made somewhat smaller than for rough, to avoid the con-

fusion that would ensue if the necessary allowance for dressing should be made upon work intended for finishing.

In conclusion, therefore, your Committee offer the following:—

Resolved, That the Franklin Institute of the State of Pennsylvania, recommend for general adoption by American Engineers, the following forms and proportions for screw threads, bolt-heads, and nuts, viz.

That screw threads shall be formed with straight sides at an angle to each other of 60°, having a flat surface at the top and bottom equal to one-eighth of the pitch. The pitches shall be as follows, viz:—

Diameter of Bolt,	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8
No. of th'd per in.	20	18	16	14	13	12	11	10	9	8	7	7	6	6	5 1/2	5	5
Diameter of Bolt,	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6
No. of th'd per in.	4 1/2	4 1/2	4	4	3 1/2	3 1/2	3 1/2	3	3	2 7/8	2 3/4	2 5/8	2 1/2	2 1/2	2 3/8	2 3/8	2 1/4

The distance between the parallel sides of a bolt-head and nut for a rough bolt shall be equal to one-and-a-half diameters of the bolt, plus one-eighth of an inch. The thickness of the heads for a rough bolt shall be equal to one-half the distance between its parallel sides. The thickness of the nut shall be equal to the diameter of the bolt. The thickness of the head for a finished bolt shall be equal to the thickness of the nut. The distance between the parallel sides of a bolt-head and nut, and the thickness of the nut shall be one-sixteenth of an inch less for finished work than for rough.

Resolved, That a copy of these resolutions be forwarded to the Quarter Master General, Chief of the Bureau of Steam Engineering of the Navy, and the Chiefs of Ordnance for the Army and Navy, and Chiefs of the Engineer and Military R.R. Corps, and the Supt. and M.M. of R.R. Co.'s, requesting them to use their influence to promote the adoption of a uniform system of screw threads, bolt-heads, and nuts, by requiring all builders under any new contracts to conform to the proportions recommended.

Resolved, That a copy of these resolutions be also sent to all Mechanical and Engineering Associations or Institutes, and the principal Machine and Engine Shops in the country, with a request that they will use their influence in the proposed system.

Resolved, That this Committee be now discharged.

Wm. B. Bement,	*Firm of Bement & Dougherty.*
C. T. Parry,	*Supt. Baldwin's Locomotive Works.*
J. Vaughan Merrick,	*Firm of Merrick & Sons.*
John H. Towne,	*Firm of I. P. Morris, Towne & Co.*
Coleman Sellers,	*Eng. Wm. Sellers & Co.*
B. H. Bartol,	*Supt. Southwark Foundry.*
Edward Longstreth,	*Foreman Baldwin's Locomotive Works.*
James Moore,	*Firm of Matthews & Moore.*
Wm. Sellers,	*Firm of Wm. Sellers & Co.*
Algernon Roberts,	*of the Pencoyd Iron Works.*

On motion, it was *Resolved*, That the Report and the Resolutions appended, be printed in the next number of the *Journal*, and that the opinion of persons interested in the subject be invited.

Mr. Caleb P. Jones moved that the adoption of the report be postponed until the next meeting, which was amended by Mr. Thomas Shaw, by adding—"and that the report be printed for the use of the members."

On motion of Mr. J. Vaughan Merrick, seconded by Mr. C. P. Jones, it was ordered that the report, and the resolutions appended, be printed in the next number of the Journal of the Institute, and that the opinions of persons interested in the subject be invited.

Nominations were made for Officers, Managers, and Auditors of the Institute for the ensuing year.

The Board of Managers reported donations to the Library, from The Royal Astronomical Society, the Royal Society, the Royal Geographical Society, the Commissioners of Patents, the Society of Arts, the Institute of Actuaries, the Statistical Society, the Chemical Society, and the Zoological Society, London; Matthew B. Jackson, Esq. Sheffield, England; the Royal Irish Academy, Dublin, Ireland; T. Oldham, Esq., Superintendent of the Geological Survey of India, Calcutta; the Natural History Society, Montreal; the Literary and Historical Society, Quebec; and the Magnetic Observatory, Toronto, Canada; Hon. Wm. D. Kelley, U. S. Congress, the Smithsonian Institution, Frederick Emmerick, Esq., and Chas. Colné, Esq., Washington, D. C.; F. H. Storer, Cambridge; and Alonzo Tripp, Esq., Roxbury, Massachusetts; Young Men's Institute, Hartford, Connecticut; the Louisville Water Co., Louisville, Kentucky; the Managers of the State Lunatic Asylum, Utica, N. Y.; the Chamber of Commerce, the Mercantile Library Association, the American Institute, John Wiley, Esq., and D. Van Nostrand, Esq., City of New York; the Board of Water Commissioners, Jersey City, N. J.; the Mercantile Library [illegible] Chase, Esq., Isaac B. Garrigues,

ERRATA.

In Mr. Osborne's paper on Photo-lithography, page 57, lines 9 and 14 from the bottom, for "*Photographic*" read "*Photo-lithographic.*"

Page 59, 18th line from the bottom, for "*that*" read "*which.*"

From periods the most remote, the necessity for producing copies of graphic delineations of all kinds, has been keenly felt, and various methods were employed towards that end as civilization progressed. In early times the hand of the copyist was the only means available, and his labors were chiefly devoted to the reproduction of manuscripts and records of importance. The arduous work of the scribe however, proved inadequate to the wants of mankind; and in

fusion that would ensue if the necessary allowance for dressing should be made upon work intended for finishing.

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No. of th'd per in.	4 1/2	4 1/2	4	4	3 1/2	3 1/2	3 1/4	3	3	2 7/8	2 3/4	2 5/8	2 1/2	2 1/2	2 3/8	2 3/8	2 1/4

The distance between the parallel sides of a bolt-head and nut for a rough bolt shall be equal to one-and-a-half diameters of the bolt, plus one-eighth of an inch. The thickness of the heads for a rough bolt shall be equal to one-half the distance between its parallel sides. The thickness of the nut shall be equal to the diameter of the bolt. The thickness of the head for a finished bolt shall be equal to the thickness of the nut. The distance between the parallel sides of a bolt-head and nut, and the thickness of the nut shall be one-sixteenth of an inch less for finished work than for rough.

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COLEMAN SELLERS, *Eng. Wm. Sellers & Co.*
B. H. BARTOL, *Supt. Southwark Foundry.*
EDWARD LONGSTRETH, *Foreman Baldwin's Locomotive Works.*
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A paper was read—*On a Practical Photographic Process, and its applications*, by J. W. Osborne, Esq., of Australia.

I am happy to have it in my power to respond to your flattering invitation to attend at the present meeting of the Franklin Institute, and shall have much pleasure in bringing under your notice the photographic process which bears my name, and to which I have devoted my attention for several years.

From periods the most remote, the necessity for producing faithful copies of graphic delineations of all kinds, has been keenly felt, and various methods were employed towards that end as civilization progressed. In early times the hand of the copyist was the only means available, and his labors were chiefly devoted to the reproduction of manuscripts and records of importance. The arduous work of the scribe however, proved inadequate to the wants of mankind; and in

addition to the literature of that time, there existed also other creations by men of genius, expressive of their highest thoughts and aspirations, which he could not copy; but which were eagerly sought after by the masses of the people as sources of pleasure or instruction. Out of these wants and these desires, grew the noble arts of wood and copper-plate engraving; in connexion with them the printing-press soon followed; and publication with its mighty influence upon the world, became a great reality.

Almost within our own day, Senefelder made his great discovery and worked out his admirable method of printing from stone. To his great talents as an inventor, to his enduring zeal and enthusiasm, and to his single-mindedness as a man, the world is largely indebted. Lithography has not only supplied us with beautiful pictures of undying value, peculiarly its own; but it has also cheapened artistic illustrations for all classes, by the facilities it offers for rapid multiplication in a variety of styles. The cheapness too, with which wood engraving is now produced and the vast improvement in that art during the last thirty years, I believe to be in great part due to the existence of lithography.

Photography, as a method of re-producing the work of the pencil, or the press, next claims our attention. By means of this wonderful discovery, we are enabled to copy and multiply originals of every description with many advantages hitherto unknown. The great mass of the public, is beholden to it for a not inconsiderable acquaintance with the schools of Ancient and Modern Art, and our professional and scientific men no less so for copies of rare documents or drawings, in cases where rapidity, or extreme fidelity, are matters of importance. Photography differs essentially as a means of re-production from the engraving processes to which I have already referred, not only in the details of the peculiar operations which together constitute the process, but fundamentally in its very nature. For, whether we print from wood, or stone, or copper, the engraving upon the block or plate, must in the first instance be produced by the hand and eye of an artist, to effect which his appreciation of form and size is called into requisition, and the power of imitation and execution has to be cultivated. The result by these means approaches excellence in proportion to the care, talents, and experience of the workman, and as he is not infallible, it will always fall short of absolute perfection. Photography on the contrary, embraces within itself, all the necessary resources to accomplish the end in view. The forces which produce the picture, when once called into play, perform their part infallibly, and without the volition of the operator at every step; all he can do is to give them their object, to modify their intensity, to determine when and where they shall commence to act, and for how long a period. As far as outline and form are concerned it is quite possible to produce an absolute fac-simile of any original by this means. The first step in the process (the production of the negative) which corresponds to the execution of the engraved plate or block, is effected by photography in a few minutes, and at an inconsiderable cost, irrespective of the complexity of the

original. Its advantages, therefore, as a copying agent can hardly be over-estimated, and they are very generally appreciated and acknowledged. In some respects however, photography as a means of multiplying impressions or proofs stands far below the common printing processes. Its many excellencies are to a certain extent counterbalanced by the fact that positive photographic prints, as at present produced, are not permanent, sooner or later they will fade and lose their value. Their production also is at best a slow process, and therefore costly, and printing operations depend too much upon the state of the weather over which the operator has no control. In one word photography is unexceptionable as a means of producing a faithful transcript of an original, and transcends all other methods; but as a means of multiplying copies, it is unable to compete with the press. This being the case, the thought soon presented itself to experimenters to combine photography with one of the ordinary printing methods, to copy by the one process, and multiply by the other, and accordingly, a great number of inventions have been made, having for their object the production of engraved plates, or raised blocks, or drawings on lithographic stone, by photographic agency which would at the same time prove capable of yielding impressions in the press. Of the nature of these numerous processes, and of their value, and the success they have met with, it is not my intention to speak on the present occasion; my wish is to bring under your notice the particular form of press-photography which I called myself into existence, and which for certain purposes at least, I believed to be unequalled.

My process is designed for the re-production of line drawings and engravings of every description, and the substance upon which I work and from which I print is lithographic stone. The problem I had to solve may be stated as follows:—*From a given original existing as a black and white delineation, to produce by the chemical properties of light a fac-simile upon stone, identical in character with an ordinary lithographic drawing, that has been by the necessary preparation fitted for the printer.*

Before proceeding to describe the way in which this is accomplished it may be well to state for the better elucidation of my subject, that lithographic stone consists of a certain variety of carbonate of lime, which is found in the celebrated Solnhofer quarries, in Bavaria, and is exported to this, and other countries in the form of slabs a few inches thick, and of various sizes. For use, one surface of such a stone is ground smooth and level, and sometimes polished, and upon this the artist executes his work. If a line be drawn upon such a surface with a pen dipped in a peculiar ink, the essential characteristic of which is that it contains fatty matter in solution; or with a crayon made of a mixture of fat, wax, and resinous substances colored with lampblack,—or if we bring in any other way a greasy line upon the stone, and having done so, subject the whole surface to the action of a slightly acidulated gum-water, the face of the stone so prepared will be found to have undergone a change, and to have acquired certain remarkable properties which it did not possess before; in fact we have produced

a true lithographic drawing, and from the line above mentioned we can now print impressions in the press. The changes which have taken place by the action of the fatty matter, acid, and gum, upon the carbonate of lime are rather complex, they are for the most part little understood and indifferently explained; the subject is indeed a difficult one, and an exhaustive examination of the phenomena which present themselves in lithography, would form an important and extensive treatise. On the present occasion I must content myself with stating in general terms, that the printing capabilities of a lithographic drawing, after "preparation" or "etching," as it is called, depend upon the adhesive attraction which those parts of the surface constituting the drawing, manifest for greasy matter brought in contact with them, and the repulsion of the same for water. They depend still further upon the converse of this state of things over the rest of the face of the stone, such portions having a strong affinity for water, and when wet, as strong a repulsion for grease. Thus a sort of antagonism is set up, and the surface of the stone is,—if I may be permitted to use the expression,—polarized, as far as its adhesive affinity for grease and water is concerned. This change in physical properties is due to the chemical combinations which have taken place; these, as before stated, are difficult to account for thoroughly, but it will suit our present purpose to bear in mind the leading fact which is this, that a portion of the greasy matter contained in the lithographic ink, enters into combination with the lime of the stone, forming a new substance with it, the boundaries of which are sharply circumscribed. This substance is an insoluble lime soap, and it is neither raised above nor depressed below the face of the stone, and yet constitutes the printing surface, the production of which is the aim of both the lithographic, and photo-lithographic artist.

To obtain a proof on paper from a stone in this condition, the following method is employed. The stone is first evenly damped with a sponge or cloth. The printer's roller charged with ink—a compound of prepared oil and lampblack—is then passed backwards and forwards over the work, whereby it deposits its ink only on the design or drawing; for the moisture on the other parts of the surface hinders its adhesion to them, and causes them to remain perfectly clean. A sheet of paper is next laid upon the stone, which is then drawn through the press; this sheet is then lifted off, and it will be found that the pressure has caused the accumulated ink upon the stone to attach itself to the paper, and produce there the desired impression. These operations are repeated for the next sheet, and so on until the requisite number is printed.

The foregoing very imperfect sketch of lithographic general principles has served at least to define what the end and aim of the photo-lithographer should be. What I have now to describe is the means whereby the hand of man may be dispened with, and its place supplied by photographic manipulations.

Let us suppose that a map has been compiled and drawn with great care, and that it is desired to multiply copies of this original in the

lithographic press. The first step in the process is to obtain a negative; for which purpose the map is placed upright upon a plan-board, and the camera opposite to it at such a distance as to give the desired ratio between original and copy. A negative is now taken on glass coated with collodion quite in the usual way, save that the greatest care is observed to avoid distortion of all kinds, and to produce a negative of the highest excellence, success in which depends entirely upon the knowledge, judgment and experience of the operator.

A sheet of plain, positive photographic paper is now coated on one side with a mixture consisting of gelatine, softened and dissolved in water, to which a quantity of bichromate of potash and albumen has been added. The paper, evenly covered with this fluid, is dried in the dark, when it will be found possessed of a smooth glassy surface, and a brilliant yellow color. This surface is still further improved by passing it through the press in contact with a polished plate.

A suitable piece of positive photo-lithographic paper thus manufactured is now to be exposed to the action of the light under the negative of the map already described. This is accomplished in an ordinary pressure-frame, the time required varying from ten or fifteen seconds to several minutes, according to the brightness of the weather; but it is always short compared with that necessary for the production of a picture on paper prepared with chloride of silver. The positive thus obtained presents itself to the eye as a brown drawing upon the clear yellow of the sheet. If the prepared surface of the paper were now moistened with water, and the attempt made to apply printing ink to it, we would find a strong tendency in the albumo-gelatinous surface, to behave towards greasy and watery substances in a manner quite analogous to that already stated as peculiar to a lithographic stone while printing. We would also find that the solvent action of water at any temperature is quite incapable of removing the picture which the sun has imprinted upon it. The light, in fact, has so acted upon the chemical substances brought together upon the surfaces of the paper, that the organic matter is no longer soluble. These are the characteristics of the change due to exposure, which we have to remember.

But the exposed photographic copy of the original is not moistened, or subjected to any solvent action at this stage of the proceedings; it is, on the contrary, covered all over, while dry, with a peculiar lithographic ink known as transfer ink, which is accomplished by running it through the press with its face in contact with a stone which has already received a coating of such ink. After it is separated from the blackened stone it will be found to have brought away with it an evenly distributed film of inky matter forced by the pressure into intimate contact with the unexposed, as well as the exposed portions of the surface. This operation is known as "*blacking*" the positive print; that now to be described is called "*coagulation*," its object being to effect a change of that nature upon the albumen contained in

the coating of organic matter. For this purpose moisture and heat are necessary, and both are applied very simply, by letting the blackened photographic copy swim upon the surface of boiling water with its inky side upwards, for it is important not to wet that with hot water. After the lapse of a certain period, determined by the experience of the operator, he proceeds to the next step in the process, that of "*washing off.*" For this purpose the print is laid upon a smooth surface, such as a plate of glass or porcelain, and friction with a wet sponge, or other suitable material, is applied to the black inky coating, under which the photographic image still exists, and to develop which is now the object in view. The operator soon becomes aware that the moisture which percolated through the paper from the back, has exerted a softening or gelatinizing influence upon the gelatine in the sensitive coating; it has caused it to swell, and to let go its hold upon the ink. But this change does not extend to those parts of the coating which were acted on by light; in other words, to those places which were unprotected by the opacity of the negative, they remain intact, uninfluenced by the solvent or moistening effect of the water. Accordingly, the operator finds a fac-simile of the original map gradually develop under his hand as he continues the friction. This process is proceeded with until all traces of ink are removed, save those required to form the picture, which must be clear and distinct in all its details. Abundance of hot water is then poured over it, so as to remove every particle of soluble matter, and it is then finally dried, which completes its preparation. We are now possessed of a photograph in lithographic ink, identical in every respect with the original, not simply upon paper, but upon albuminized paper, a matter of much importance, as will be presently explained. The presence of the albuminous layer under the picture, is the result of the coagulation which took place while the print was swimming on the hot water; after that change no amount of washing could remove it, although the gelatine was not proof against such treatment.

A stone to which a fine smooth surface has been imparted is now slightly warmed, and put in the lithographic press; upon this is placed inverted the positive print, after it has been damped by lying between moist paper, and the whole is then passed repeatedly through the press. On examination the paper will now be found to have attached itself firmly to the stone, so that some force is required to separate the two. When the former is removed it brings with it, its albuminous coating which gives to it while damp a parchment-like appearance; but the ink is gone, it has left the paper for the stone, and on the latter we find a reversed drawing of the map, one, which after it has been properly "prepared" will print as well, as if it had been drawn by hand. The rationale of this method of transfer is easily understood; the greasy ink having a great affinity for the substance of the stone, combines with it to form a lithographic drawing in the strictest sense of the word, and while this is taking place the damp albumen upon the paper, holds the sheet in its proper place so as to

prevent a shift of any kind, and enable the pressure to be applied as often as the operator wishes.

I have thus overcome the difficulties of the problem I undertook to solve; I have succeeded in making light do the work of the lithographic artist, as far as copying the original is concerned. The printer can now multiply impressions from such a stone with as much facility as if the drawing upon it was of ordinary, and not photographic origin.

Having now explained the leading operations upon which my photo-lithographic process depends, it may not be out of place to add a few words respecting its history. The immediate cause which prompted me to undertake the invention and elaboration of a process of this kind, was the great necessity which existed in the British colony, Victoria, for some simple, expeditious, and exact method, by which the numerous maps connected with the sale of the public lands might be copied, printed, and published by the Government for the information of the colonists. I was asked to see what could be done in this matter, and the result was the process as I have described it this evening; the invention dating from the 19th of August, 1859. It was instantly adopted by Government, the first map for sale having been produced on the third of September following. Instructions were given to the field surveyors and draftsmen, so as to secure uniformity, and in a wonderfully short time a revolution was effected in the department, which proved very advantageous. Since that time, several thousand different original maps, direct from the hands of the surveyors have been photo-lithographed, whereby a most important saving in time and money has been effected, as well as numberless advantages gained, to which I need not refer in detail. In 1861, the Victorian Government built, at my suggestion, and according to my plan, a large and well appointed Bureau, consisting of many rooms for the more efficient practice of this art, which has been since then in full operation. In the same year the Parliament of Victoria, awarded me by a unanimous vote the sum of £1000, in recognition of my services. I have since my return to Europe resigned my position as chief of this office; but I cannot forbear looking back with pleasure and pride to the time that is past; to its labor and its difficulties, and to its success and triumph also. My process is not the oldest, but it was the first which proved practically valuable, and the Photographic Office in Melbourne, was the first, and for a long time the only establishment where photo-lithography was turned to practical account.

In Berlin, where I recently resided for the purpose of developing my invention in relation to art subjects, my process has been adapted for the production of a large number of illustrations of an important Government work, the Prussian Expedition, to Japan, China, and Siam. They are all of them reproductions of drawings in pen and ink, by the artist who was sent out with the Expedition. The originals are thought to possess much merit, and it would be a great pleasure to

me to lay them before the members of the Franklin Institute this evening; that is obviously impossible, but the photo-lithographs which I submit are very faithful fac-similes of them, and will, I doubt not, command your approval. Those which I exhibit—six large plates, and twelve smaller ones, with two maps—are published with the first part of the work.

In conclusion, allow me to draw your attention to a few of the applications which this method of reproduction admits of. For convenience sake, originals susceptible of being copied, may be divided into two great classes. Those which have to be drawn on purpose, or which the advantages offered make it desirable to draw: and those which exist already, and to which this method of exact copying imparts a new interest and importance.

The former class includes several kinds of mechanical drawing, such as maps and plans, architectural designs and drawings of machinery, and in addition to these, pen and ink sketches, involving true artistic talent. Of maps, I have already spoken in the present paper; the application of photo-lithography to them, has advantages too obvious and overwhelming, to require lengthy comment from me; still there are some things which remain to be said, and which I ought not to omit. The original of a new map must be drawn in every case before it can be engraved and published. By applying photo-lithography directly to such an original we save an immense expense, and we accomplish in a *few days*, what, under ordinary circumstances, would occupy *months*. These are advantages which every map publisher will appreciate; but it is only those who are in charge of large governmental departments, on whom the laws of the country, or the exigencies of the times, throw heavy responsibilities; who are daily called upon to supply exact geographical information in their possession, and find their means inadequate; it is only such persons who can fully realize the great benefit which would arise from the employment of a method of reproduction, combining rapidity with absolute fidelity. I could add much more on this theme; I might expatiate upon the gain or loss to the nation, which must often depend upon the publication of a map at the right time; the importance of abundant geographical information to the well-being of the people, both in an educational and material sense, and many other interesting considerations which would naturally flow from the discussion of this part of my topic; but the subject is too large to enter upon at length, and I will content myself with referring to the question which may be raised as to the quality of map-work produced by this means. A moment's reflection will show that this depends entirely upon the way in which the original is drawn; the fac-simile of a good map will be itself a good lithograph, and vice versa. But there is a certain superiority which photo-lithography enjoys to which I have not as yet referred—namely, the power of *reduction*. By this capability of the camera, we are not only enabled to publish originals on various scales; but the draftsman in preparing a map, is at liberty to draw large and

rapidly without distress to his sight, and the result is more satisfactory than would be achieved by the greatest labor and care bestowed upon fine and tedious details.

The value which photo-lithography has for the artist who draws with pen and ink for publication, cannot be over-estimated. If he is a man of elevated genius, he will not willingly permit the creations of his mind to appear before the public after they have passed through the hands of a mechanical copyist, which the engraver generally is. This feeling it was, which led many of the great masters, and even artists in our own day to devote themselves to the difficult study of etching: they wished to produce something which could be multiplied in the press, and yet bear the stamp of their own individuality upon it; and they endeavored to accommodate themselves to the use of the etching needle and acid, and all the uncertainties attending them. The artist may now draw upon paper the material to which he is accustomed, and his original he can ultimately retain uninjured; and yet every thought and feeling in it can be reproduced and given to the world with absolute fidelity. This is a boon which artists in Europe have began to avail themselves of, an example which I am convinced their American brethren will not be slow to follow.

The second class of originals suitable for being copied by photo-lithography, embraces those which are already in existence, such as impressions of all kinds taken in the press, together with documents of a historical or personal nature, printed or written by hand. Neglecting the latter on the present occasion, let us consider for a moment the vastness of the store of classical engravings and etchings which, since the introduction of copper-plate printing, have descended to us from the great masters in art.

This is a rich field for the photo-lithographer, one which is inexhaustible and capable of supplying him with an ennobling occupation of undying interest. The production and free circulation amongst the public of works so replete with beauty and lofty sentiment, now difficult of access in consequence of their price and rarity, would be indeed, in my mind, an undertaking of national importance well calculated to advance mankind; but one which I cannot do justice to within the limits of the present paper.

I cannot close this description of my process, and its applications without recording the opinion of a gentleman well qualified to form one; but inclined to a severe judgment from the circumstance that by it, his own work was, and is yet to be published. I refer to the landscape painter, Mr. A. Berg, of Berlin, who accompanied the Japanese Expedition. In writing to me after the appearance of the first part of the Government work which is now before the Society, he says:—

"The President of the Royal Commission, appointed to superintend the publication of the East-Asiatic Travels, has requested me to express to you his grateful acknowledgments of your great services, and disinterested exertions in this work. It gives me particularly

great pleasure to be enabled to make this communication to you, and I avail myself of the opportunity to convey to you also my own sincere thanks for your assistance in this work. *You have solved the most difficult problems in this field; problems, the solution of which I myself despaired of, until the successful result was placed before my eyes.* The question whether pen and ink drawings can be multiplied by photo-lithography, and thus made valuable to the artist, is determined by this work."

At the conclusion of his address, Mr. Osborne pointed out and explained the plates exhibited on the walls of the Hall. He also showed reproductions of engravings and wood-cuts, together with map-work of various kinds, chiefly the result of his labors in Australia.

Mr. John Sartain spoke in high terms of the beauty of the plates exhibited to them this evening. They possessed a depth of color and finish which he had rarely, if ever seen equalled by lithography in any form. He had been deeply interested in Mr. Osborne's description of his process, and particularly wished to endorse that part of the lecture having reference to the reproduction of engravings. Even under circumstances the most favorable, when the engraved plate was still to be had, a transfer from it to the stone rarely gave a satisfactory lithograph, and this was more particularly the case with works of high merit. The reason was, that the transfer ink used for this purpose appeared upon the sheet used for transferring, in lines of very appreciable thickness, due to the depth to which those lines were cut in the copper; the ink presented in fact an embossed surface. When such an impression was pulled through upon the stone, the ink became crushed, and the lines of the lithograph lost their purity. Mr. Osborne, made use of a very small quantity of ink without appreciable elevation which could not, and as the specimens before them most satisfactorily demonstrated, did not crush. When the engraved plate was unattainable, and this was the rule and not the exception, Mr. Osborne's process stood quite alone, he had never seen results to compare with it.

Mr. M. P. Simons asked Mr. Osborne to inform them how it happened that he exhibited no photo-lithographs of portraits? He did not see why his process would not produce them and photographs of a similar character as well as line work.

Mr. Osborne explained that the invention was not calculated to render what was known as photographic half tone; other experimenters had devoted themselves to this part of the subject, and it was no doubt a most attractive and important question. The difficulties which attended the production of perfect gradation or half tone, depended upon the fact that in lithographic work the stone was made to represent such tints by giving it a grain, and the graduated shade upon an impression consists not of an even wash; but of an assem-

blage of little black dots, or markings of varying size, and at different distances from each other. A photographic negative from nature, such as a portrait on the contrary, possessed no such structure, and to produce the former description of drawing by the aid of a negative constituted the real difficulty.

Professor Frazer, said that he had listened to Mr. Osborne's address with the deepest interest. It had often been a source of surprise to him, that more had not been achieved in this direction, particularly when he looked back to what had been accomplished in the early days of the photographic art. He had in his possession a number of views published in Paris, which had been taken as daguerreotypes from natural scenes; they were chiefly architectural subjects, and had been partly etched upon the plate, and partly worked up by hand; but he considered them very interesting exemplifications of what could be done, for notwithstanding the hand work, they still showed their truthful photographic character. Of Mr. Osborne's process, and the work produced by it, he could not speak too highly; they were not from nature, but he was not convinced that the branch of the art thus brought into a perfect and practical form, was of less value and importance than that which aims at the copying of natural objects.

Professor Van der Weyde said that he must differ from Mr. Osborne, as regards the rendering of half tone, or mezzotint effects by photo-lithography; Professor Seely, of New York, had shown him some specimens of the kind from nature, he had forgotten by whom they were; but they demonstrated beyond a doubt the possibility of attaining such effects.

Mr. Osborne, replied that it was far from his intention to imply in any of the remarks he had made, that photo-lithographic half tone was a thing unattained or unattainable; he had only referred to the difficulty, not the impossibility of producing it. On the contrary, he had seen a great deal of work of this sort, some of it very beautiful. A number of experimenters had devoted themselves to its attainment alone, such as Poiterin, Asser, Toovey and others. The specimens referred to by the last speaker, were probably by Cutting and Bradford, of Boston, or by their process. Still, although much had been done, much yet remained to do, for none of the half tone processes were, as far as he, the speaker knew, sufficiently certain and practical to give them a high mercantile value. He believed this would be the case one day, and at no very distant period; but there was a wide difference between the value of the process which produced *work*, and that which furnished specimens only. This subject was a very extensive one, and a comparative enumeration and description of the various processes would alone furnish more than material for a single lecture.

Mr. Coleman Sellers thought Mr. Osborne, had not done his process justice in passing so hastily over the question of the saving

effected by it. It was true all processes in which photography played so important a part as it did in that now before them, must be economical. It was easy to see that whether an original was crowded or not, the camera copied it with equal facility; while in the engraver's calculation, the difference in the intricacy, and amount of detail were important items. Reasoning in this way he felt and probably others also, that a great saving must be effected by the application of photo-lithography; but he would be glad if Mr. Osborne could give them some more distinct data to go upon.

Mr. Osborne, replied that the question of economy was partly one of time, and partly one of money; he would endeavor to make some statements which would illustrate the saving that might be effected in both. The lecturer then drew the attention of the meeting to a map produced under official auspices in Melbourne, which had been photo-lithographed and printed for the purpose of establishing how rapidly it could be done. From the receipt of the original to the production of the first impression in the press, the time required was two hours and seven minutes. To lithograph the same map by hand would require a week at least. In the same way two maps had been compared, which he would lay before them; they were both from the same original and on the same scale; but the one was lithographed by hand, the other was photo-lithographed. The former was completed in exactly three days and a half, and cost £4 9*s.* 5*d.*; the latter, with three other maps was photo-lithographed in four hours and forty-eight minutes, and its cost was estimated at six shillings and sixpence. In like manner, on thirty-one maps produced in ten days a saving of upwards of £90 was effected, and the same would have required eighty-nine days to execute in the old way. These facts would be sufficient to show the comparative expense of producing maps by the old and the new methods. The last example quoted was work done at the ordinary rate in the daily routine of office business; in the other two cases every effort was used to ensure rapidity and economy. When pen and ink originals and engravings were copied, great rapidity was of little importance; the object in such cases was to accomplish by photo-lithography, what it was absolutely impossible to accomplish by any other known means, and if it was done within two or three days, the questions of cost might be altogether neglected.

Professor Frazer, said that he thought he expressed the sense of the meeting which he was glad to see so well attended, by proposing a cordial vote of thanks to Mr. Osborne; the members must all feel with him that they had been much interested this evening.

The vote being seconded, and put by the President, was unanimously adopted.

Mr. Osborne returned a few words of thanks and the meeting separated.

A Comparison of some of the Meteorological Phenomena of DECEMBER, 1864, *with those of* DECEMBER, 1863, *and of the same month for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	December, 1864.	December, 1863.	December, for 14 years.
Thermometer—Highest—degree, .	59·00°	60·00°	71·00°
" " date, .	7th.	14th.	2d, 1859.
" Warmest day—Mean,	52·33	54·17	62·80
" " " date,	3d.	13th.	2d, 1859.
" Lowest—degree, .	12·00	15·00	4·50
" " date, .	12th.	23d.	19th, 1856.
" Coldest day—Mean,	19·67	20·67	11·00
" " " date, .	12th.	23d.	18th, 1856.
" Mean daily oscillation,	9·83	13·26	12·17
" " " range, .	7·37	6·54	6·45
" Means at 7 A.M , .	32·92	30·87	31·79
" " 2 P M., .	38.58	39·13	39·20
" " 9 P.M., .	35·95	34·68	34·69
" " for the month,	35·82	34·89	35·23
Barometer—Highest—Inches, .	30·411 in.	30·495 in.	30·678 in.
" " date, . .	9th.	7th.	18th, 1856.
" Greatest mean daily press.	30·362	30·423	30·611
" " date, . .	9th.	7th.	18th, 1856.
" Lowest—Inches, .	29·071	29·167	28·946
" " date, . .	21st.	14th.	9th, 1855.
" Least mean daily press.,	29·275	29·341	29·175
" " date, . .	21st.	14th.	9th, 1855.
" Mean daily range, .	0·265	0·223	0·216
" Means at 7 A.M., .	29·801	29·999	29·950
" " 2 P.M., .	29·730	29·935	29·908
" " 9 P.M., .	29·782	29·981	29·936
" " for the month, .	29·771	29·972	29·931
Force of Vapor—Greatest—Inches,	0·438 in.	0·486 in.	0·551 in.
" " " date, .	7th.	14th.	2d, 1859.
" " Least—Inches, .	·052	·051	·025
" " " date, .	12th.	11th.	18th, 1856.
" " Means at 7 A.M., .	·152	·142	·143
" " " 2 P.M., .	·161	·156	·169
" " " 9 P.M., .	·169	·145	·156
" " " for the month,	·161	·148	·156
Relative Humidity—Greatest—per ct.,	92·0 per c.	96 per ct.	100 per c
" " " date,	2d.	14th.	often.
" " Least—per ct.,	26·0	35·0	23·0
" " " date, .	1st.	24th.	15th, 1861.
" " Means at 7 A.M.,	77·3	74·1	77·2
" " " 2 P.M.,	64·8	59·8	65·3
" " " 9 P.M.,	74·8	68·5	75·0
" " "for the month	72·3	67·5	72·5
Clouds—Number of clear days,* .	3	10	8·6
" " cloudy days, .	28	21	22·4
" Means of sky cov'd at 7 A.M.,	73·2 per c.	56·1 per c.	64·0 per c.
" " " " 2 P.M.,	77·7	56·8	63·9
" " " " 9 P.M.,	77·7	47·4	48·4
" " " for the month.	76·2	53·4	58·8
Rain and melted Snow—Amount,	4·754 in.	4·871 in.	3·711 in.
No. days on which Rain or Snow fell,	19.	10·	10·6
Prevailing Winds—Times in 1000	s72° 54′w·158	N72° 0′w ·243	N62° 15′w·271

* Sky one-third or less covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the year 1864, *with those of* 1863, *and of the last* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	1864.	1863.	13 years.
Thermometer—Highest—degree, .	96·00°	95·00°	100·50°
" " date, .	June 26th.	Aug. 10th.	July 21st '54
" Warmest day—Mean,	89·67	88·50	91·30
" " " date,	June 26th.	Aug. 10th.	July 21st '54
" Lowest—degree, .	4·00	5·00	—5·50
" " date, . .	Feb. 17th.	Feb. 5th.	Jan. 23d '57
" Coldest day—Mean,	7·00	11·17	—1·00
" " " date, .	Feb. 17th.	Feb. 4th.	Jan. 9th '56
" Mean daily oscillation,	13·79	14·63	15·04
" " " range, .	5·27	5·39	5·53
" Means at 7 A. M., .	50·40	49·98	49·77
" " 2 P. M., .	59·66	59·21	59·88
" " 9 P. M., .	53·75	53·21	53·19
" " for the year,	54·60	54·13	54·28
Barometer—Highest—Inches, .	30·411 in.	30·671 in.	30·704 in.
" " date, . .	Dec. 9th.	Feb. 4th.	Jan. 28th '53
" Greatest mean daily press.	30·362	30·553	30·611
" " date, . .	Dec. 9th.	Jan. 18th.	Dec. 18th '56
" Lowest—Inches, . .	29·071	29·127	28·884
" " date, . .	Dec. 21st.	Jan. 16th.	Ap. 21st '52
" Least mean daily press.,	29·150	29·298	28·959
" " date, . .	Nov. 4th.	Jan. 16th.	Ap. 21st '52
" Mean daily range, .	0·152	0·157	0·156
" Means at 7 A. M., .	29·772	29·879	29·880
" " 2 P. M., .	29·730	29·835	29·840
" " 9 P. M., .	29·775	29·877	29·867
" " for the year,	29·759	29·864	29·862
Force of Vapor—Greatest—Inches,	0·895 in.	0·980 in.	1·059 in.
" " " date, .	Aug. 2d.	Aug. 10th.	June 30th '55
" " Least—Inches, .	·022	·027	·013
" " " date, .	Feb. 17th.	Feb. 4th.	Feb. 6th '55
" " Means at 7 A. M.,	·314	·316	·323
" " " 2 P. M.,	·321	·322	·338
" " " 9 P. M.,	·338	·332	·344
" " " for the year,	·324	·323	·335
Relative Humidity—Greatest—per ct.,	100 per ct.	100 per ct.	100 per ct.
" " " date,	Jan. 18th.	Jan. 21st.	often.
" " Least—per ct.,	18·0	15·0	13·0
" " " date, .	Mar. 9, Ap. 7	April 26th.	Ap. 13th. '52
" " Means at 7 A. M.,	72·0	74·5	75·7
" " " 2 P. M.,	53·9	56·7	57·1
" " " 9 P. M.,	68·9	70·5	72·0
" " " for year,	64·9	67·2	68·3
Clouds—Number of clear days,* .	94	93	109
" " cloudy days, .	272	272	256
" Means of sky cov'd at 7 A. M.	61·8 per c.	63·4 per c.	60·0 per c.
" " " " 2 P. M.	66·6	63·9	60·8
" " " " 9 P. M.	52·4	49·9	45·8
" " " for the year,	60·2	59·1	55·5
Rain and melted Snow—Amount,	46·730 in.	49·642	45·436 in.
No. of days on which Rain or Snow fell,	128·	143·	128·
Prevailing Winds—Times in 1000,	s82°22′w·220	n65°19′w·149	n75°53′w·205

*Sky, one-third or less covered at the hours of observation.

A General Abstract of the Meteorological Observations made at Philadelphia during the year 1864.—By Prof. James A. Kirkpatrick.

Latitude 39° 57½′ N. Longitude, 75° 10½′ W. from Greenwich. Height of Barometer fount, sixty feet above mean tide in the Delaware River.

1864. Months.	Thermometer.									Barometer.								Dew Point.			
	Maximum.	Minimum.	Range. Monthly.	Range. Mean daily.	Mean daily oscillation.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average.	Highest.	Lowest.	Range. Monthly.	Range. Mean daily.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average.
	°	°	°	°	°	°	°	°	°	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	°	°	°	°
January,	65	7	58	5·85	13·74	29 89	37·48	32·24	33·20	30·271	29·257	1 014	·206	29 886	29 847	29·913	29·882	21·19	23·13	23·25	22·52
February,	57	4	53	7·18	15·29	30·55	40·57	34·74	35 29	30·375	29 284	1·091	·182	29·792	29·742	29·796	29·777	21·89	20 56	23·44	21·96
March,	59	20	39	5·11	13 55	34·35	45·07	39·03	39·48	30·131	29 184	·947	·176	29·723	29·656	29·699	29·693	25·93	25·57	28·15	26 55
April,	75	32	43	5·27	15·40	44·90	55·58	48·45	49 61	30 048	29·310	·738	·122	29·730	29 699	29·755	29 728	35·74	36 83	37·80	36·79
May,	86	41	45	5·03	16 61	62·53	73·55	65·15	67 01	30·000	29·379	·621	·108	29 663	29·627	29·665	29·652	53·40	54·78	55·92	54·69
June,	96	51	45	5 69	17·42	67·33	78·23	70·03	71 86	30·087	29·296	·791	·127	29·812	29·777	29·805	29·798	55 25	56·22	58·27	56 58
July,	94	60	34	3 81	15·73	72·39	83·48	76 97	77·61	30 066	29·518	·548	·114	29·784	29·747	29·783	29 771	60 58	59 92	63·24	61·25
August,	96	61	35	2·73	11·71	75·26	84·19	78·43	79·29	29 938	29 437	·501	·082	29 726	29 694	29 726	29·715	65·14	64·90	67 08	65·71
September,	81	51	30	4 82	12·30	63 22	70·78	66·32	66·77	30·117	29·450	·667	·103	29·786	29 760	29 795	29·780	54·80	54·72	55·78	55·10
October,	75	36	39	4·56	13·16	50·11	59·37	55·18	54·22	30 022	29·218	·804	·129	29·715	29·674	29 726	29·705	41·39	41·72	43·53	42·22
November,	69	25	44	5·84	10·80	41·30	49·22	44·57	45·03	30·347	29·080	1·267	·208	29·848	29 803	29·849	29·833	34·23	35·38	35·76	35·12
December,	59	12	47	7·37	9 83	32 92	38·58	35·95	35 82	30·411	29·071	1·340	·265	29·801	29·730	29·782	29·771	26·33	27·15	28·58	27·35
Annual means,	96	4	92	5·27	13 79	50·40	59 66	53·75	54·60	30 411	29 071	1·340	·152	29·772	29·730	29·775	29 759	41·32	41·74	43·40	42 15
Winter,	65	4	61	6 52	14·10	30·44	39·06	33·89	34·46	30 495	29·167	1·328	·204	29 892	29·841	29 897	29·877	22·22	23·14	23·93	23·10
Spring,	86	20	66	5·14	15·19	47·26	58 00	50 88	52·05	30·131	29 184	·947	·135	29·705	29·661	29·706	29·691	38·36	39·06	40 62	39·35
Summer,	96	51	45	4·08	14·95	71·66	81·97	75 14	76·26	30·087	29·296	·791	·108	29·774	29·739	29 771	29 761	60·32	60·35	62 86	61·18
Autumn,	81	25	56	5 07	12 09	51·54	59·79	54·69	55·34	30·347	29·080	1·267	·147	29 783	29 746	29·790	29·773	43·47	43 94	45·02	44·14
Means for 13 years,	100½	−5½	106	5·53	15·04	49·77	59·88	53·19	54·28	30·704	28·884	1·820	·156	29·880	29 840	29·867	29·862		43·27		